DOCUMENT RESUME

ED 080 573 TM 003 089

AUTHOR	Abravanel, Eugene
TITLE	The Development of Spatial Awareness and Representation in Children. Final Report.
INSTITUTION	George Washington Univ., Washington, D.C. Dept. of Psychology.
SPONS AGENCY	National Center for Educational Research and Development (DHEW/OE), Washington, D.C. Regional Research Program.
BUREAU NO	BR-0-0405
PUB DATE	Feb 73
GRANT	OEG-3-70-0042
NOTE	61p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Cognitive Development, Concept Formation; Elementary Grades; *Geometric Concepts; Kindergarten; *Perceptual Development; Space Orientation; *Spatial Relationship; Task Performance; Technical Reports; *Topology

ABSTRACT

The growth of spatial awareness and representation was studied in children between ages five and nine. A group of thirteen tasks was administered to subjects three times with periods of approximately six months among sessions. The tasks were selected to measure understanding of projective spatial properties (straight line trajectories, perspective, and the coordination of perspectives), Euclidean properties (length, angle and area), topological properties (proximity, enclosure, order, etc.), and the coordinates of space. In general, projective spatial awareness developed from an ability to produce simple straight line trajectories, to a recognition of perspective properties in pictures and scenes, to an understanding of how to construct projective lines and to coordinate perspectives. Only by 4th grade were more than a few subjects capable of coordinating perspectives. Comprehension of the vertical coordinate of space, as well as ability to organize straight lines along the vertical axis, appeared at a younger age than a comparable understanding of the horizontal axis. Oblique projections of various kinds were consistently the most difficult, and lagged behind acquisitions for the vertical and horizontal coordinates of space. Awareness of topological properties was found among the youngest children, but here too a progression from simpler to more complex achievements was found with age. (Author/KM)

FEB 21

NCERD

TM

Final Report

Project No. 0-0405
Grant No. OEG-3-70-0042

Eugene Abravanel
Department of Psychology
The George Washington University

Title: The Development of Spatial Awareness and Representation in Children

February 1973

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development
(Regional Research Program)

Table of Contents

List of Figures

ABSTRACT

The growth of spatial awareness and representation were studied in children between ages five and nine. A group of thirteen tasks was administered to subjects three times with periods of approximately six-months among sessions. The tasks were selected to measure understanding of projective spatial properties (straight line trajectories, perspective, and the coordination of perspectives), of Euclidean properties (length, angle and area), and of topological properties (proximity, enclosure, order, etc.). Understanding of the coordinates of space also was included among the properties investigated. In general, projective spatial awareness developed from an ability to produce simple straight line trajectories, to a recognition of perspective properties in pictures and scenes, to an understanding of how to construct projective lines and to coordinate perspectives. Only by 4th grade, were more than a few subjects capable of coordinating perspectives.

Comprehension of the vertical coordinate of space, as well as ability to organized straight lines along the vertical axis, appeared at a younger age than a comparable understanding of the horizontal axis. Oblique projections of various kinds were consistently the most difficult, and lagged behind acquisitions for the vertical and horizontal coordinates of space. Awareness of topological properties was found among the youngest children, but here too, a progression from simpler to more complex achievements was found with age.

INTRODUCTION

The present report summarizes the aims, methods and findings of a study that sought to investigate the development of spatial awareness and representation in children between the ages of five and nine. A short-term longitudinal approach was used in which the same groups of children were studied over a period of fifteen months.

Classical conceptions of knowledge traditionally have seen fit to raise the questions, "What is our knowledge of space?", and "How does the average person arrive at his knowledge of space?" (Kant, 1787; Cassirer, 1957). With such questions, philosophers, physicists, psychologists and educators have placed knowledge about space on a par with other fundamental aspects of knowing such as awareness of time, of identity and change, and of cause-effect interdependences. Yet, as with all the others in the list, our typical individual soon runs out of words when asked to describe his knowledge of space in specific or general terms. Space is naively interpreted as a container in which all the contents of reality reside. The probing of interplanetary space certainly has enlarged the average man's conceptions of this "container", but most of us search desperately for words to convey further the actual understanding of space that we possess. In a sense we are "spatial illiterates" who possess a reasonably developed practical knowledge of spatial relations, but who lack the means to symbolically elaborate and communicate this knowledge.

On the other hand, mathematicians, especially geometers and topologists, have been long interested in the analysis of space, in determining the rules which govern the relationships among points, lines and surfaces in space. Physicists, engineers and architects can, and do, analyse space geometrically, topologically or projectively, and place great importance on both understanding and using knowledge of planes and surfaces, of rotations, translations and transformations in space, of two-dimensional, three-dimensional and n-dimensional space, and so forth.

Beyond the typical inability to say more than a few words about our understanding of space lies an even greater difficulty in dealing with abstract space, with the space or spaces of mathematics and science. Even in the college classroom, I have occasionally raised issues about our ability to intuit spatial relations and to imagine operations in space, only to find that even college undergraduates are not especially adept at conceptualizing spatial relations. And, once beyond the more familiar spatial relationships such as up-down, inside-outside, near-far, etc., many of these verbally sophisticated adults show serious deficiencies in their capacity for understanding and intuiting the results of movement in space, or imagining spatial

transformations. I cannot help but wonder whether the deficiencies that I have sensed even for college students are not related to the hardships involved in learning mathematics and science. The lack of facility, that I judge to be present, in dealing with anything involving complex spatial thinking, may be an important factor in understanding the mental torpor present in so many high school and college students when learning geometry, or when trying to grasp physical concepts of force, movement, gravitational fields, and so forth. But, we must keep in mind that these accomplishments represent some of the higher reaches of spatial knowledge and intuition. At the lower levels, which most of us attain during childhood, are problems of a more practical and limited grasp of spatial relations. Achievements as those of an infant learning to rotate an object to get at its reverse side, or a toddler detouring around a sofa to locate the ball that rolled under it, are the kinds of sensori-motor learnings about space that underlie higher achievements.

When a child of school age truly generalizes his sensori-motor knowledge that a straight line is the shortest distance between two points, or that two irregular staircases can be measured in a way that enables him to compare their lengths precisely, we see evidence of a still higher level awareness of spatial properties. And, in confronting a problem such as tying knots or in determining the projective size of an object as it recedes in the distance, we witness the growing person demonstrate his increasing ability to operate with spatial constructs. The rates at which individuals achieve these attainments will vary with both endowment and experiences, and, at the present time, we possess no adequate calculus for differentiating these determinants. Direct tuition presumably influences the attainment of the basic level of spatial awareness, but with the exception of a few acquisitons, we do not know how the process of learning these relationships from others proceeds. It may be that our most challenging educational problems in this area will be to insure that all children acquire the fundamental spatial-cognitive abilities, and then to determine how we can enlarge this level of understanding to include the higher reaches of spatial awareness and representation.

The present study may be viewed in the light of these long term goals, but its immediate aims were considerably more modest. First, by designing a descriptive-developmental study of young children's spatial development, we hoped to assay levels of performance at three grades, kindergarten, 1st grade, and 3rd grade, for a set of spatially significant abilities. The levels of attainment at each grade would provide normative information regarding specific abilities, and might be expected to shed light on some general patterns of abilities as well. Second, in addition to comparing spatial abilities at three cross-sections of the age continuum, by using a longitudinal design, and assessing performance several times over a period

of fifteen months, it would be possible to describe rates of change for the same sample of subjects. This leads to our third major interest, which was more age independent, and that was to characterize the sequence of spatial development across our battery of tasks. For this purpose, age of attaining an ability would be less important than the order in which abilities are demonstrated. Although a central tendency can usually be determined for the age at which an ability level is attained, there is always variability due to individual differences. However, even where rates of attainment vary among children, the sequence of ability growth may be quite regular. Our aim was to examine sequences independently of grade placement, in order to obtain a picture of ordinal characteristics in spatial growth. An understanding of the order of attainments in a reasonably delimited area of cognitive growth may elucidate the conditions that are sufficient for achieving a level of intellectual functioning. It could, at least, produce more useful hypotheses about determinants of growth.

A fourth interest had to do with individual differences between boys and girls. Previous researchers (cf. Macfarlane-Smith, 1964) have presented findings that boys were superior to girls in the development of spatial abilities. We wondered whether this would be true for the kinds of spatial abilities we had decided to study; abilities that are not directly related to mechanical interests or prior experience with gears, tools, levers and pulleys. Sex differences, where found, are never easy to explain, but the reliability of differences still needs to be established in the area of spatial growth. Given that systematic and reliable differences are found for boys and girls, educational implications might follow directly.

Much of the older literature on the growth of spatial abilities is summarized by Macfarlane-Smith (1964) and by Werner (1948). Factor-analytic studies have typically found a spatial factor to be present in most general abilities tests. However, a spatial factor has often been labeled, but rarely analysed. Perhaps this reflects the difficulty that even psychologists have had in conceptualizing spatial understanding. Piaget and his collaborators (Piaget and Inhelder, 1956) have made some important strides in the analysis and conceptualization of spatial growth. Beginning with his studies of infants, Piaget (1954) has paid special attention to the way in which simple sensori-motor spatial achievements are made during the first two-years of life, and has attempted to sketch some important changes in the growth of topological, Euclidean and projective levels of spatial awareness. Subsequent research by Laurendeau and Pinard (1970) has corroborated major portions of this groundbreaking research effort. A number of other investigators have been eager to determine whether one task in particular, the "coordination of perspectives", might not have been made overly complex by Piaget and Inhelder, thereby obscuring the possibility that younger children may be capable of coordinating perspectives (Flavell, 1968; Shantz & Smock, 1966). These more recent studies indicate that the specific materials used in the task, and the methods employed, affect the overall difficulty, and whether a child will demonstrate an ability to adopt other perspectives.

Rationale for the Spatial Tasks Investigated.

Any practical short-term study of the growth of spatial awareness would, of necessity, be selective in the abilities chosen for study. One of the spatial areas that interested us most was the growth of projective space. This involves the ability to deal with linear aspects of space, to understand that straight lines may be projected from any point in space, and that an individual's perspective at any position in space follows something like a straight line path which makes some objects (or sides of objects) visible, and obscures others. We selected and developed a group of tasks which might be expected to tap levels or stages of the projective awareness of space. One task involved the ability to conceive straight line motion along a given trajectory (Task 8), or to recognize the point of intersection between two trajectories. A second task (Task 11) required further demonstration of the ability to construct projective straight lines, but this time with discrete objects, and over a larger field. A pair of related measures (Task 9 and 10) tested for the child's awareness that a person's position in space influences what he will, and will not, see. We wondered whether the youngest children would show total egocentrism (i.e., since they see the entire scene, so should any figures placed within it) with these problems. One of these two tasks involved the understanding of perspectives as demonstrated by how an object drawing should look from different viewpoints, while the second task demanded a similar form of understanding from a three-dimensional village layout. At the higher level (Tasks 9 and 10), problems were added to determine whether subjects knew how to coordinate perspectives such that they could mentally assume the perspective of another, and construct a scene from that viewpoint rather than from their own. This would provide evidence for an understanding of projective relations such as left-right, before-behind, and higher-lower in the field.

Another group of tasks was included to tap spatial abilities that are potentially related to the linear aspect of space. One of the tasks in this group tested for a child's ability to conserve length (Task 4) across figural transformations. Piaget has reported that children below ages seven or eight rarely conserve length. We were interested in determining how performance on conservation of length would compare with performance on the projective tasks. Similarly, a sample of the child's understanding of measurement (Task 5) was included in order to determine the place that unitizing and composing linear sections might have in the progress of spatial awareness. The ability to take another perspective involves the mental "shifting" of ones position in space or, alternatively, remaining stationary and mentally rotating objects in the visual field. We incorporated a simpler version of this skill (Task 13) in a series of procedures where objects had to be rearranged in space and changed ordinally after rotation.

Additional tasks involving figural reproduction (Task 2) and pattern reproduction (Task 3) were included in order to assess the progress of our subjects in dealing with topological, Euclidean, and projective aspects of space when performing with concrete and stable configurations. In addition, the ability to recognize objects from incomplete drawings (Task 1) was added for purposes of testing the children's capacity to imagine shapes and fill-in figural information from memory and imagination. We reasoned that this ability might be related to performance on other tasks requiring mental rotations and perspective shifts. Finally, two problems that measure awareness of the vertical and horizontal axes of space (Tasks 6 and 7) were included for purposes of assessing the subject's understanding of the stable projective nature of gravitational verticals, and the equally stable horizontal plane produced by liquids in a container. As such, this pair of tasks surveys the ability to comprehend spatial relations within a wide framework, a spatial coordinate system, as opposed to the more limited sphere of influence produced by immediate containers or adjacent planes and surfaces.

METHOD

Subjects

The subjects (Ss) for this research were drawn from three age groups: kindergarten (ages 4 yrs., 6 mos. to 5 yrs., 10 mos., mn.= 5 yrs., 4 mos.), 1st. grade (ages 5 yrs., 9 mos. - 7 yrs., 1 mos.,=6 yrs., 5 mos.), and 3rd. grade, (ages 7 yrs., 10 mos. - 9 yrs., 8 mos., mn.= 8 yrs., 6 mos). These ages refer to Section 1, Fall 1970. For Session 2, Ss were all approximately six-months advanced in age, and for Session 3, Ss at each age level were all approximately fourteen-months older than at the time of Session 1. There was a total of 72 experimental Ss (36 girls and 36 boys) and 20 control Ss.

Subjects were drawn from several sources: a private school and two public schools, all within Metropolitan Washington, D.C. Most children were judged to be of middle-class socio-economic background, with a few children coming from lower-class families. Families presented a mix of blue-and white-collar occupations. The majority of children were white, with fewer than ten children black or judged to be racially mixed.

Materials and Procedures

The materials were constructed for each of the thirteen tasks, except in one case (Block Design) where a standardized test item was adopted. The composition of materials is presented below along with procedures for each task.

Task 1: Recognition of Incomplete Pictures.

Materials. A set of ten pictured objects (bird, table, bell, telephone, tricycle, shoe, dog, horse, sailboat and umbrella) with four drawings varying in degree of completion for each object. The materials for this task were patterned after the incomplete drawings developed first by

Street (1931). An outline drawing of a table, for example, may be difficult to recognize if a sufficient portion of the outline is removed. As more outline is added, recognition is made easier. The S's assignment was to recognize the object portrayed from drawings containing a maximum of deleted contour. For each picture in the series of ten, four drawings were made which varied from most to least complete. The S was presented first with the least complete drawing, and if unable to recognize it, was then given the next drawing in the series. In this way a S could achieve correct recognition on either the first, second, third or fourth drawing.

Instructions to the S were:

"I have some pictures to show you. They are all pictures of things that you know. In these pictures, some of the lines have been left out so that you have to guess what they are. Each picture has four parts. The first part has just a very few lines in it. If it reminds you of something take a guess, it doesn't matter if you guess wrong. If the picture doesn't remind you of anything, just shake your head and I will show you the next picture. The second one has more of the lines in it. The third one has still more of the lines and the fourth has almost all of the lines in it, so that you can tell what it is."

Task 2: Design Copying.

Eight figures were constructed for design copying. Each figure was drawn on a card (4" X 8") in black ink (Figure 1). The S was presented with each card in succession beginning with Design 1. He was asked to copy it as well as he could on a sheet of paper. Each drawing was made on a separate sheet of paper in order to prevent comparisons with previous drawings.

Task 3: Block Design.

The materials and procedure for this taks were taken directly from the WISC (Wechsler Intelligence Scalė for Children) test of the same name. The Ss were administered the test according to stand procedures (cf. Wechsler, 1949).

With Ss under eight-years, four blocks were placed before S; he was invited to examine them, and to take note of the fact that there were different colors on the different sides. Then, the experimenter (E) opened the testing booklet to Design A and the S was instructed to watch as she constructed the first design. The S was asked to judge whether the design had been properly made, and then was told to make the same design with

another four blocks. The S's performance was timed. When dealing with Ss eight-years and older, the typical WISC procedure was followed, with both demonstration and testing beginning with Design C. A S could progress through Design VII or be discontinued after two consecutive failures.

Task 4: Conservation of Length.

Materials for this task consisted of ten blocks (1 3/4 X 3/4 X 1/2 in.) of the ordinary "dominoes" variety, and a small toy man. The S was told that E would build some paths with the dominoes, rather like sidewalks. Then two "paths" were assembled (Figure 2) and S was asked to indicate whether the paths were equal in length. The S was further asked, "If the little man walked along all of this path (demonstrated) and all of this path (demonstrated) would he walk the same on both paths - would he walk just as far on one path as he would on the other path?"

The S was then quizzed: "What if one day, this path (B) were changed to look like this (C), and then the little man walked down all of this path (A) and all of this path (C) - both demonstrated - would he still walk just as far on each one?" Regardless of the answer, the S was asked "Why?" At times, the word "Road" was substituted for "path" in order to communicate more effectively. Each S was carefully queried in order to be certain of the basis for his judgment. For each S, two transformations (C) and (D) were made.

Task 5: Measurement of Length.

Materials. Measurement of length was assessed with the use of four sets of line drawings (Figure 3) and two measuring "devices", a 3/4 in. X 2 in. cardboard strip, and a 3/4 in. X 4 in. cardboard strip.

The S was presented with the first pair of . ings and was asked to judge whether they were of equal lengtł llowing his judgment, the S was given the shorter measuring device, and asked if he knew how to use it for measuring the lines and finding out whether his judgment was correct - i.e., whether the two lines were the same length, or one was longer. If the S said that he did not know know how to use the measurer, or if he used it incorrectly, he was shown the proper method of measuring with the device. As the S measured lines, he was urged to measure the entire line drawing, and was told also that if there were differences in the lines, that they would be large differences, not small ones. The S was asked, additionally, to give the number of measured units in each line, this serving as a check for the E as to how well S was measuring.

The above procedure was repeated with the second set of line drawings. If the S succeeded at all in measuring either Set 1 or Set 2, then Sets 3 and 4 were presented. Whereas, if S failed to show an understanding of measurement with the two simpler sets, he was discontinued for this task.

With Sets 3 and 4, a further level of measurement ability was required. The S was told that this time he was to measure one of the line drawings with the small measuring device, whereas the other line was to be measured with the larger measuring device (with which he was then provided). The choice of which of the pair of drawings was to be measured with either small or larger measurer was left to S. In order to succeed at this measurement task, S had to understand that the smaller measurer was one-half the larger, and that equivalence of measurement could be maintained by keeping this fact in mind. After taking his measurements, S was probed to see whether he understood the relationship.

Task 6: Awareness of the Vertical.

The materials for this problem were: A styrofoam mountain facsimile (18 in. X 12 in. X 11 in.) covered with plasticine, four small (1-1/2 in.) evergreen tree facsimiles, and two drawings of evergreen trees growing on a mountain (Figure 4).

The S was oriented to the mountain with one of the slopes directly in front of him. He was shown the trees and asked to plant them (all four) on the side of the mountain so that they pointed the way real trees point when they grow on the side of a mountain. As the S planted the trees, he was urged once again to point them the way that trees actually grow.

After tree-planting was completed, the S was presented with a sheet of paper on which E drew the two slopes of a mountain. The S was instructed to draw four trees on the slopes of the mountain. If necessary, E demonstrated the drawing of a simple stick tree.

Lastly, S was presented two drawings of trees on mountain slopes, a was asked to choose the picture which showed how trees really grow on mountain sides (Figure 4).

Task 7: Awareness of the Horizontal.

Materials were a clear Plexiglass cylinder (6-1/2 in. high X 4-1/2 in. diameter) two-thirds filled with colored water, an opaque covering sack for the cylinder, and drawings of an empty cylinder positioned at 0, 45, 90, 135, and 315 degrees.

The procedure was as follows: the S was given the drawing of the cylinder at 0-degrees and a pencil. With the cylinder before him, S was told to "draw the water the way it looks in a jar, and use a straight line to show the tops of the water." Once the line was drawn, S was asked to scribble-in the region of the container that held the water (at 0 degrees this was the bottom of the cyliner). The cylinder was then placed into the covering sack, and tilted to one of the above angular positions. The S was given the outline drawing positioned at the same orientation as the cylinder's and was instructed to indicate the water level as well as the region that contained the water. The order of angular positions was randomly varied among Ss. After all five positions had been presented, the cylinder was removed from its covering sack and the appearance of the water level at 315 degrees demonstrated. Following this opportunity to view the actual water level, the cylinder was returned to the covering sack, and the entire series repeated. In this way, the S had another opportunity to demonstrate awareness of the constant horizontal orientation of liquids in a container.

Task 8: Awareness of Spatial Trajectory

For this task, a set of twelve drawings (duplicated on ditto sheets 8-1/2 in. X 5-1/2 in.) of airplanes flying through clouds were assembled (Figure 5). For one subset of six drawings, each sheet depicted a single airplane entering a cloud at either 30, 60, 90, 120, 150 or 180 degrees. In the case of the second subset of six drawings, each sheet depicted two airplanes entering a cloud from different positions, with angular separations of 30, 60, 90, 120, 150 or 180 degrees.

The single airplane subset was presented first in that it was judged to present fewer coordinations and should, therefore, precede the more difficult assignment. With the first drawing, S was instructed to mark with an X at the edge of the cloud to show where the airplane would fly out of the cloud if "it flew straight ahead in a straight line." The instructions were repeated for each additional drawing.

The double airplanes subset proceeded in a similar manner. The S was instructed that each airplane was flying straight ahead in a straight line, and that he should mark the point where the two airplanes would meet inside the cloud. Again, instructions were repeated for each drawing.

Task 9: Recognition of Perspectives.

Materials consisted of six objects (a toy pig, a slice of cheese with a mouse atop it, a toy penguin, a toy cat with a prominent tail, a pencil, and a small facial tissues box. For each object, drawings were made from each of four positions (top, front, rear, side) representing different views of the object. Finally, a small toy man was included for "viewing" each object.

The toy man was placed near the object at one of the positions represented on the drawings. The S was instructed to "find the picture that shows how the man sees the object from where is standing." Care was taken to make this instruction clear. After the S had chosen the picture which he believed represented the man's perspective, the pictures were removed, shuffled, and laid out for the second judgment. In this way, each S proceeded through three perspectives for each of six objects. Order of presentation of the three positions, as well as order of the six objects, was varied randomly.

Task 10: Representation of Perspectives.

The materials consisted of two "village scenes" composed of wooden figures approximately 1 in. high. Scene I consisted of a woman and a man facing each other at a distance of a few feet in the center of what might be a village square. Buildings, trees, animals behind a fence, a soldier guarding an official building, comprised the scene. Scene II represented the railway station area of a village, and contained a railroad flagman positioned to the side of a train, a depot, a woman on the other side of the square, some houses, a small wall with boys behind it, and some animals. The objects in each scene were fastened to a board which fixed their positions. In addition, for each scene the child was presented with a duplicate set of objects which he could manipulate and place on a second board.

The procedure was to present the S with one of the human figures (e.g., trainman) and to indicate that he place it in the same position on the empty board that it occupied on the board with stationary figures. With the figure in place, the S was instructed to place on his board "just the things that the trainman (or other figures) could see from where he is standing in the village." Instructions were repeated as the S performed the task, and if the S worked slowly or hesitantly, he was requested to repeat the instructions in order to be certain that he understood them. The S was also requested to indicate when he had finished the task.

At this point E recorded the placements of objects made by S. This procedure was followed for both human figures in Scene I and Scene II.

Task 11. Construction of a Straight Line.

In this task, twelve plasticine balls with matchsticks planted in the centers were used to simulate fence posts. Also, a large cardboard disc (24 in. diameter) was used.

The task required construction of three straight lines using the simulated fence posts.

Line I (Parallel). Two "posts" were placed about 20 in. apart, and approximately 1 in. from the edge of the table. The posts were identified as endposts of a fence, and the S was instructed to build a straight line between the endposts. After he had constructed the lines, S was asked to indicate how he could be certain that was straight, and how he could look at the line to check and see if it were straight.

Line II (Oblique). The two endposts were placed at a 45 degree angle with respect to the table edge, with a distance of 20 in. between them. The S was instructed again to build a straight line between endposts. As before, S was queried about its straightness, and about a method that he could use to verify straightness.

Line III (Chord). For this construction, the endposts were placed at two points on the circumference of the cardboard disc, and the S was told to build a straight line of posts between these points. In effect, this construction involved forming the chord of a circle, an an angular displacement from S in order that it not be paralled to S's body axis. As before, S was asked to verify straightness after having built the line.

Task 12: Coordination of Perspectives.

Materials consisted of one large model and one small model of each: barn (8 X 4 X 5 in. & 2 X 1 X 1-1/2 in). silo (9 in. X 3 in. diameter & 3 in. X 1 in. diameter), fence (6 in X 3 in. & 2 in. X 1 in.), horse (3 in. high & 1-1/2 in. high), farmer (3 in. high & 1-1/2 in. high), green felt square (15 in. X 12 in. & 6 in. X 4 in.) for ground.

The large model barnyard was set up on the larger green ground in a predetermined pattern (Figure 6). The smaller green ground was placed approximately 12 in. in front of the model barnyard. The S was requested to walk around the barnyard, to observe how it looked from each side, and to note where everything was located. It was pointed out that everything in the scene looked slightly different from each side. Then, the S took a seat facing the barnyard, the larger model of the farmer was presented, and the E discussed with with S how photographs would look if the farmer took pictures of

the barnyard from different sides. Next, the S was given the following instructions: "If the farmer took his first picture here, and if we pretend that this little man (small model) is the farmer with his camera can you build the barnyard for the little farmer so that it looks exactly the same for him as it does for the big farmer?"

Subjects were generally capable of constructing the first view (essentially ego oriented) with no further prompting. However, where necessary, the S was "talked through" the placement of each piece. Next, the large farmer was moved to another position, and the S was instructed to "build the barnyard for the little farmer the way it looks to the big farmer." He was encouraged to make it exactly the same as it looked to the big farmer. If the S appeared to hesitate, it was explained that whereas the little farmer could not be moved, all the other items could be brought to the small farmer to make the little barnyard the same as the large one. After S constructed his version of the small barnyard, he was questioned about it in order to test the limits of his comprehension.

Al Ss constructed four views of the scene: the ego-oriented view, 90 degrees to the right, 180 degrees, and 225 degrees. The order of positions was randomly assigned across Ss.

Task 13: Linear Order: Reversal, Transformation and Anticipation.
Materials consisted of various colored beads, two rigid wires (5 in.), one hollow opaque tube (12 in. X 1 in. diameter).

Reversal of linear order. A selection of beads was laid in front of the S. Taking six beads, each of another color, E strung them on a wire in full view, naming them as she strung. This strand was placed in front of S, the starting point on his left and the terminus on his right. The S was instructed to string his wire so as to produce the same strand of beads, except that he was to start his string with the bead on his right. The bead was named by color and pointed to by E. He was carefully instructed to begin with that bead and to maintain the same order of beads as appeared on the strand before him. Questions are to be answered only by repeating the instructions, the S having to decide what was desired.

Transformation of circular to linear order. The S was presented with a circle of ten beads strung on a wire, and resembling a necklace. The S was then given a straight wire, and was told to string his beads in the same order, but in the form of a straight line instead of a circle. He was given the starting bead and told to proceed. If he asked, he was told that he could string in either direction.

Anticipation of linear order. This problem consisted of two anticipation tasks. In the first, the S was presented with three differently colored beads, the E using an equivalent set of three. Each of the three beads was inserted slowly into an opaque hollow tube which was held parallel to and directly in front of S. The color of each bead and its order (first, second or third) were announced by E as the beads were inserted. Following this, the S was asked to predict the color of the bead that would emerge from the other side of the tube first, second and third. The S was told to arrange his set of three beads in a row which corresponded to the order in which the beads would emerge. Afterwards, E tipped the tube and showed S the order of emergence for the three beads. If the S failed to predict the correct order, the procedure was repeated a second time, the order of the beads remaining the same.

The second task raised the level of complexity involved in anticipating order. The S was asked again to watch carefully what was done with the beads. Three beads were slowly inserted, with each named as it was placed into the opaque tube. Then the tube was rotated 180 degrees. The S was instructed to predict the order of emergence, using his three beads to duplicate the order. The tube was tipped, and the beads set out in a row above the S. Only one trial was given.

RESULTS

Findings of this longitudinal study will be presented in two parts. First, results for each of the thirteen tasks will be given in terms of the main variables: Grade, Sex and Session. Using analyses of variance, (Winer, 1962) for each of these variables, main effects will be presented, and possible interactions reported. Where a task consisted of several subtasks or subparts, analyses were made to determine whether there were significant differences among subtasks. Finally, experimental and control groups were compared at the time of Session 3, and the significance of this difference is presented.

In the second part of this section, findings for the separate tasks will be interrelated in order to provide a view of the pattern of spatial development as presented in performances on the thirteen tasks.

For each of the thirteen tasks, group variances were found to be homogeneous in accordance with Cochran's test (Winer, 1962).

Task 1. Recogniton of Incomplete Pictures.

Scoring for this task was accomplished by assigning a score from 1 to 4 for each of the ten incompleted pictures. A score of 4 was given for recognition of the pictured object from the most incomplete drawing, a 3 for recognition from the drawing that was somewhat more complete, etc. Thus, the maximum score that a S could achieve was 40. Basic results are summarized in Table 1.

Grade level was a significant factor in differentiating performance on this task. ($\underline{F}$ = 27.10, df = 2/58, p<.001). Newman-Keuls comparisons indicated that significant (p<.01) improvement was made with each successive grade. Likewise, significant improvement occurred between Sessions I and II, but not thereafter.

No significant Sex effect was found for this task ($\underline{F}$ = 20.15, df = 9/5.22, p>.01), demonstrating that level of difficulty varied among pictures.

Experimental and Control group performances were largely similar, with 3rd. Grade experimental boys showing the only markedly superior performance over the comparable control group. The analysis of variance was barely significant (F = 4.45, df = 1/82, p<.05), and such a relatively low $\underline{F}$ value, when compared with other $\underline{F}$ values for this task, cannot be accorded great weight. This is especially true in the case of dichotomous data such as those for this task.

Task 2. Design Copying

Each of the eight designs was scored independently, and the range of possible scores varied between one and five per design. With eight designs to copy, the maximum score that a $\underline{S}$ could achieve was 50. The general scoring procedure was as follows: A score of $\underline{1}$ was assigned to very poor copies that were essentially unrecognizable. A score of $\underline{2}$ was given for drawings that showed some approximation to the model, but were very poorly executed. A $\underline{3}$ indicated that the basic gestalt was more apparent, but the figural qualities were still only approximations. A score of $\underline{4}$ was given for a good copy which preserved most of the essential features, and missed only some of the finer points of detail. And, a $\underline{5}$ was assigned for a competent rendition which included all the features of a figure, with accurate proportions, where straight lines were approximately straight, and where joins between lines were made in the proper places. We did not require a perfect copy, but one which preserved the figural properties in the manner described.

Table 2 presents the basic results for this task. The main effect of Grade was significant ($\underline{F}$ = 69.70, df = 2/58, p<.001). Paired comparisons among grades were made with the Newman-Keuls procedure and the significance levels for these comparisons are given in Table 2. These analyses demonstrate significant improvements for each grade over the previous one.

All designs clearly were not equal in difficulty. ($\underline{F}$ = 45.51, df = 7/406, p<.001). The rank-order of di-ficulty from easiest to hardest (without regard for statistical significance of the difference between designs was: Designs 2, 4, 1, 3, 5, 7, 8 and 6. One can safely say that Designs 2 and 4 were reproduced best by the largest number of $\underline{S}$s at all ages.

No significant Sex effect ($\underline{F}$ = .74, df = 1/58, p$>$.05), was obtained for this task, indicating that boys and girls were rather comparable in design copying ability. This was reinforced by the fact that no Sex X Design or Sex X Grade interactions were found.

The main effect of Sessions proved to be significant ($\underline{F}$ = 4.64, df = 2/116, p$<$.001), and further analysis by means of the Newman-Keuls procedure indicated that the difference was to be located between Session I and Session II, with the latter showing the higher scores. No significant improvement was found for Session III.

Significant interactions did result in the following cases: a Grade X Session interaction ($\underline{F}$ = 4.56, df = 4/116, p$<$.01), a Grade X Design interaction ($\underline{F}$ = 5.81, df = 14/406, p$<$.001) and a Session X Design interaction ($\underline{F}$ = 3.30, df. = 14/812, p$<$.001). However, the significant interaction F values were much lower than the significant main effects F values.

The performance of Control groups Ss at the time of Session 3 was significantly ($\underline{F}$ = 4.87, df = 1/82, p$<$.05) better than that of Experimental group <u>Ss</u>, with most of the difference appearing at the 1st grade.

<u>Task 3. Block Design.</u>

Basic results for this task appear in Table 3. The main effect of Grade was statistically significant ($\underline{F}$ = 31.39, df = 2158, p$<$.01). Paired comparisons among grades were made with the Newman-Keuls procedure, and the significance levels for these comparisons are given in Table 3. Significant (p$<$.01) improvement was made by each successive age-group when constructing Block Designs.

A Sex effect was found, with males showing significantly ($\underline{F}$ = 5.12, df = 1/58, p$<$.01) better performance. The better performance by boys appeared during Session 3 for 1st. Graders and was present consistently at all sessions for 3rd. Graders.

Similarly, the main effect of Sessions was significant ($\underline{F}$ = 43.56, df = 2/116, p$<$.01) indicating an improvement over the course of the three testings. A Grade X Session interaction also proved to be significant ($\underline{F}$ = 4.21, df - 4/116, p$<$.01). On the other hand, the difference between Experimental and Control groups was not significant ($\underline{F}$ = .01, df = 1/82, p$>$.05).

<u>Task 4. Conservation of Length.</u>

The basic results are summarized in Table 4. Scoring varied between 0 and 3, with one point given for each of three lines that was conserved properly. The main effect of Grade proved to be highly significant ($\underline{F}$ = 58.37, df = 2/58, p$<$.001) once again. Paired comparisons among grades showed that significant progress was made between grades 1 and 3 (Newman-Keuls p$<$.01), but that 1st grade children were not significantly more able conservers of length than kindergarteners.

A small, but significant ($F = 2.86$, df = 4/116, $p < .05$) Grade X Session interaction was found. And, the main effect of Sessions was clearly significant ($F = 14.00$, df = 2/116, $p < .01$), with increasing numbers of conservers at each session.

No significant sex differences appeared for this task. Experimental and Control group Ss differed significantly ($F = 6.37$, df = 1/82, $p < .05$), with more control Ss achieving conservation of length in kindergarten and 1st grade. By 3rd grade, most children had achieved conservation, such that both groups were highly similar.

Task 5. Measurement of Length.

Scoring for Measurement of Length was more complicated than for some of the other tasks. A score of 1-point was assigned for each line judgment of the four that was correct. Additionally points to a maximum of four were given as follows: 3-points for accurate usage of the measuring device; 2-points for reasonably good understanding of the fact that the lines could be measured by the device, but where the measuring procedure was highly fallible; 1-point for an elementary demonstration that the lines could be measured; and one further point was given if the relationship between the small and large measuring devices was understood. This made for a total possible point score of eight.

Findings are summarized in Table 5. The main effect of Grade was significant ($F = 63.86$, df - 2/58, $p < .01$). Comparisons among grades with the Newman-Keuls procedure produced evidence of significant ($p < .01$) advances for each grade over the previous one.

No significant sex differences ($F = 1.55$, df = 1/58, $p > .05$) emerged, but the main effect of Sessions was quite clear ($F = 21.01$, df = 2/116- $p < .01$). Performance improved significantly ($p < .05$) with each session.

A test for the difference between Experimental and Control groups proved to be nonsignificant ($F = 0.57$, df = 1/82, $p > .05$).

Task 6. Awareness of the Vertical.

This task contained three subparts or sub-tasks that assessed a S's awareness of the fact that for objects that grow (e.g., trees) the line of growth is perpendicular to the ground rather than to the slope of the surface upon which it is planted. For each sub-task (planting, drawing and recognition of correct picture) a S's performance was scored as: incorrect = 0-points, marginal = 1-point (as when some trees were correctly planted whereas others were incorrectly planted), and correct = 2-points.

Results are presented in Table 6. Once again, improvement with grade was clearly evident ($F = 23.42$, df = 2/58, $p < .001$), and Newman-Keuls comparisons showed a significant ($p < .01$) improvement with each successive grade. No significant Sex effect was found ($F = 0.32$, df = 1/58,

$p > .05$). The factor of Sessions was significant ($F = 13.31$, df = 2/116, $p < .001$), with Newman-Keuls demonstration that the major changes were between Session I and Session II ($p < .01$).

Several interactions were also significant: Grade X Session ($F = 4.34$, df = 2/116, $p < .01$); Grade X Subtask ($F = 8.62$, df = 4/116, $p < .001$); Subtask X Session ($F = 3.43$, df = 4/232, $p < .01$); Grade X Task X Session ($F = 4.02$, df = 8/232, $p < .01$). However, the interaction F values were typically lower than the main effects F values.

Likewise, a clear effect of Subtask was present ($F = 58.86$, df = 2/116, $p < .001$), and Newman-Keuls comparisons indicated that recognition of the correct drawing was passed by more Ss ($p < .01$) than were actual drawing or planting of trees; however, drawing and planting subtasks were not significantly different from each other, Ss doing about as well with one as with the other.

A comparison of Experimental and Control groups for Session III was not significant ($F = 1.04$, df = 1/82, $p > .05$).

Task 7. Awareness of the Horizontal.

The basic data summary for this task appears in Table 7. Eight judgments of water level were made by each S. For each of the eight judgments, the S was scored as passing (0) or failing (1). In addition, a S's performance on the first block of four judgments, prior to demonstration compared with performance following the demonstration. Also, an analysis by subtask was made for performance with different angles of tilt.

As for the treatment of main effects, the average improvements with Grade were significant ($F = 48.40$, df = 2/58, $p < .001$). Newman-Keuls comparisons demonstrated that significant ($p < .01$) improvements were made by each grade.

The main effect of Sessions ($F = 15.83$, df = 2/116, $p < .001$) was also significant. Here Newman-Keuls comparisons indicated that the Session II and Session III scores were higher than Session I scores, but that scores for the two later sessions were not significantly different from each other.

A Sex effect was present for this task, with boys scoring significantly ($F = 13.54$, df = 1/58, $p < .001$) higher than girls. The Grade X Sex interaction was also significant ($F = 5.69$, df = 2/58, $p < .01$). A plot of scores for males and females by grade clearly located the significant sex difference at the 3rd grade. The advantage for boys began to appear during 1st grade, but became significant only by 3rd Grade.

There were eight critical judgments, indications of water level, in this task. Four were made prior to demonstration, and four followed demonstration of the water level at 315 degrees. Comparing performance on the first block of four judgments with the second block, the differences proved to be significant ($F = 4.81$, df = 1/58, $p < .01$), with

the second block showing higher performance. This may be attributed to the effect of the demonstration, which seems a more plausible explanation than a general practice effect. However, one must be cautious in interpreting comparatively small F values (even where significant) when dealing with dichotomous data such as these.

Since four angles of tilt were presented to Ss, it was possible to analyse angular position of the container as a main effect. Angle of tilt proved to be significant (F = 38.62, df = 3/174, $p < .001$). Newman-Keuls comparisons demonstrated that Ss were most successful with the 90-degree tilt, next with the 45-degree tilt. The 315- and 135-degree tilts were the most difficult inclinations for which to judge the level of water in the container.

The difference between Experimental and Control groups was not significant (F = .13, df = 1/82, $p > .05$).

Task 8. Awareness of Spatial Trajectory.

Scoring for the six single airplane spatial trajectory subparts was in terms of deviation from an objective straight pathway as it would be projected through a cloud. Scoring for the six double airplane trajectory subparts was based on extent of deviation from the objective point of intersection made by two planes proceeding in straight line paths. For each subpart, scores could vary between 0 and 2. A score of 0 was assigned to lines that were wide of the mark by 1 in. or more; a score of 1 was assigned for deviations of 1/2 in. to 1 in; a score of 2 was given for deviations within 1/2 in. of an objective straight line.

Basic results are summarized in Table 8. The main effect of Grade continued to be highly significant (F = 49.87, df = 2/58, $p < .001$). Newman-Keuls indicated that significant ($p < .01$) improvements in accuracy were made with each successive grade.

There was no significant Sessions effect (F = 1.77, df = 2/116, $p > .05$). However, a strong Sex Effect (F = 20.24, df = 1/58, $p < .001$) appeared, with boys doing better than girls as a whole. The Grade X Sex interaction was very low, telling us that the higher performance of boys was distributed across grades.

A comparison of the six single airplane with the six double airplane trajectories produced no significant main effect ; however, the interaction of Single vs. Double X Session was significant (F = 3.92, df = 2/116, $p < .05$). Performance for double airplanes varied little across sessions, whereas accuracy of single airplane trajectories improved moderately between Session I and Session II.

The comparison of Experimental and Control groups was significant (F = 5.21, df = 1/82, $p < .05$), but not greatly.

Task 9. Recognition of Perspective.

Scoring for this task was based on the number of correct pictorial

identifications of the perspective modelled by E with each object. With a point given for each correct identification, and three views for each of six objects, a S could earn a minimum of 18 points.

Results are summarized in Table 9. Once again, changes with Grade were significant ($F = 40.96$, df = 2.58, $p < .01$), and Newman-Keuls comparisons pointed to significant ($p < .01$) improvements with each grade.

Improvement occurred also across Sessions ($F = 26.41$, df = 2/116, $p < .001$), with significant $p < .01$) progress being made on each successive session as shown by Newman-Keuls comparisons.

A significant Sex effect was obtained ($F = 5.25$, df 1/58, $p < .01$), with boys showing better performance than girls, on average. The greatest sex differences were found for 3rd grade Ss across all three sessions, which is reflected in the Grade X Sex interaction ($F = 2.62$, df = 2/58, $p < .05$). No other interaction was significant.

The Experimental vs. Control group comparison was not significant ($F = 1.35$, df = 1/82, $p < .05$).

Task 10. Representation of Perspectives.

Scoring was in terms of a two-level (pass-fail) classification for each view that the S was asked to represent. There were four views, and a S's score could vary between 0 and 4.

Basic results are summarized in Table 10. The main effect of Grade was significant ($F = 4.33$, df = 2/58, $p < .05$), but at a lower level of confidence than for any of the other twelve tasks. Kindergarten and 1st. grade Ss were similar in performance, as were 1st. and 3rd. grade Ss. Newman-Keuls comparisons demonstrated a significant ($p < .01$) difference only between kindergarten and 3rd. grade.

The main effect of Sessions proved to be more highly significant ($F = 8.44$, df = 2/116, $p < .001$), with Newman-Keuls revealing the points of difference between Session I and II ($p < .01$). No significant ($F = .75$, df = 1/58, $p < .05$) sex differences were found.

A highly significant main effect for Views was obtained ($F = 22.22$, df = 3/174, $p < .001$). The trainman's viewpoint in Scene I was the most difficult ($p < .01$), whereas the woman's viewpoint in Scene I and Scene II were successfully represented by more Ss ($p < .01$).

A Sessions X View interaction was significant ($F = 4.57$, df = 6/348, $p < .001$). Accuracy of representing viewpoints increased across sessions for three of the four perspectives, but declined progressively for the Trainman's view (an anomaly not readily interpretable).

Similarly, Experimental and Control groups were not significantly different ($F = 3.12$, df = 1/82, $p < .05$).

Task 11. Construction of Straight Line.

Scoring for this three subpart task was 0 or 1 for each line construction, with 0 assigned for a curved, wavy or incomplete line, and 1 assigned for a reasonably straight line.

Basic results are summarized in Table 11. The main effect of Grade was highly significant ($F = 70.88$, df = 2/58, $p < .001$), once again. Newman-Keuls comparisons demonstrated that significant ($p < .01$) improvements were made with each grade.

As for improvement across Sessions ($F = 17.63$, df = 2/116, $p < .001$), significant ($p < .01$) advances were made between Sessions II and III.

A small, but significant ($F = 5.14$, df = 1/58, $p < .05$) Sex effect was obtained, and the significant ($F = 3.23$, df = 2/58, $p < .05$) Grade X Sex interaction was examined. Males performed significantly more accurately than girls only in the 3rd. Grade.

The effect of subparts was significant ($F = 18.76$, df = 2/116, $p < .001$), and Newman-Keuls comparisons showed that Line 1 (constructed parallel to the edge of the table) was passed significantly ($p < .01$) more frequently than Line 2 (oblique) or Line 3 (chord). However, only a non-significant trend of increased difficulty for Line 3 over Line 2 was found. The interaction of Grade X Line was significant ($F = 4.49$, df = 4/116, $p < .01$), with the largest discrepancy for passing the three line constructions ocurring during the 1st. grade. In kindergarten, most Ss failed all three lines, in 3rd. grade, most Ss passed all three lines, and it was during 1st. grade that the significant variance among lines appeared.

The Experimental vs. Control group comparison demonstrated that the two groups were quite comparable ($F = .02$, df = 1/82, $p < .05$).

Since we were interested in the relationship between accuracy of straight line construction and use of the operation of sighting from one end post to the other, a separate analysis was made for this purpose. Only during 3rd. grade did a majority of Ss achieve straight line constructions. Therefore, this was the grade for which the most meaningful relationship between sighting and straight line construction could be assessed. A chi-square test showed the realtionship between sighting and straightness during 3rd. grade to be significant ($X^2 = 34.87$, df = 1, $p < .001$). For 1st. graders, of 38 cases in which straight lines were produced, 28 were accomplished without the use of a sighting operation ($X^2 = 8.20$, df = 1, $p < .01$). These findings indicate that straightness may, at times, be achieved by means other than sighting, and that younger children are more likely to employ these means. However, by 3rd. grade, sighting is employed and, correlatively, straight lines are more frequently produced.

Task 12. Coordination of Perspectives.

For each of the three perspective constructions a S was scored as passing (1) or failing (0). Thus, a S's score could vary between 0 and 3.

Basic findings are summarized in Table 12. The main effect of Grade was significant (F = 18.26, df = 2/58, $p < .001$). Newman-Keuls indicated that significant ($p < .01$) improvements were made between kindergarten and 3rd. grade, and between 1st. and 3rd. grades, but not between kindergarten and 1st. grade.

The Sessions effect was also significant (F = 19.55, df = 2/116, $p < .001$), and Newman-Keuls indicated a significant ($p < .01$) advancement with successive sessions.

No significant (F = 1.69, df = 1/58, $p > .05$) Sex effect was found.

Likewise, the differences in performance among the three views was not significant (F = 1.19, df = 2/116, $p > .05$), but the Grade X View interaction was significant (F = 3.75, df = 4/116, $p < .01$). Yet, plotting this interaction demonstrated only a small decrease for the 3rd. graders on the 225 degree perspective.

Also, no significant difference (F = 2.97, df = 1/82, $p > .05$) was found between Experimental and Control groups.

Task 13. Linear Order, Reversal Transformation and Anticipation.
For each of the three subtasks, a S was scored as either passing (1) or failing (0). Thus, scores could vary between 0 and 3.

Table 13 summarizes results for this task. The main effect of Grade was significant (F = 9.45, df = 2/58, $p < .001$), and Newman-Keuls located the points of significance ($p < .01$) between Kindergarten and 3rd. Grade; no significant advance for the set as whole was made between 1st. and 3rd. grades.

The effect of Sessions was also significant (F = 14.97, df = 2/116, $p < .001$), and Newman-Keuls revealed a significant ($p < .01$) improvement with each session.

There was no significant (F = .32, df = 1/58, $p > .05$) difference between males and females.

The three subtasks were, however, significantly (F = 53.04, df = 3/174, $p < .001$) distinguishable in terms of difficulty. Newman-Keuls comparisons demonstrated that reversal of linear order, transformation of circular to linear order, and anticipation of direct order were all of approximately equal difficulty ($p < .05$). Only anticipation of reversed linear order proved to be more difficult, and was passed by significantly fewer Ss. The Grade X Task interaction was significant (F = 2.29, df = 6/174, $p < .05$) as was the Grade X Session, (F = 2.42, df = 4/116, $p < .05$), but neither was large. With dichotomous data, these interactions need not be given heavy emphasis.

The Experimental vs. Control group comparison proved to be significant at a minor level, (F = 4.72, df = 1/82, $p < .05$), with the experimental groups performing better on average.

A Comparison of Performance Across Tasks

One way of treating data of this kind to determine whether the order of task difficulty sheds light on underlying developmental processes is to see whether the tasks form a reasonable scale. A Guttman (Edwards, 1957) scalogram analysis was carried out on the data for Session III. The Coefficient of Reproducibility was .87, and the Coefficient of Minimal Marginal Reproducibility was .63. This analysis suggests that performance on the 13 tasks approximated the characteristics of a scale. That is, there was a substantial degree of order in the patterns of individuals S's responses, with mastery of any given item presupposing mastery of the easier items. This scale was derived empirically, rather than on the basis of prediction from theorectical propositions.

In order to submit the data for scalogram analysis the thirteen tasks were examined for subtasks-whole task homogeneity, and for intercorrelations among all tasks and subtasks. From these analyses, the following decisions were made: (1) The scalogram analysis would be better approached by submitting results for Ss X Subtasks; (2) Those subtasks that had very low or negative correlations with other subtasks would be eliminated.

On these grounds, 69 subtasks were arranged for scalogram analysis. Performance for several subtasks (Coordination of Perspectives: 315 degrees angle; Representation of Perspectives: Scenes 1, 2, 3 and 4) was eliminated from the analysis because intercorrelations with other tasks were very low. Items that show very low or negative correlations with most other items are not orderable meaningfully with the larger set.

An examination of the percentages of Ss passing each item (Table 14) showed the scale to be a progressive continuum from least to most difficult, with no strikingly large percentage changes between adjacent tasks. Yet, to the extent that performance for the 69 items approximates a scale, we have reason to believe that children succeed in meeting the demands imposed by "easier" subtasks prior to those presented by the "harder" ones.

Projective Straight Lines

The only subtasks that were passed by all Ss at the time of Session 3 were two from Task 8 (Straight Line trajectory involving a single airplane where the projection was vertical ( ) the other was a double airplane with a vertical projection ( ). Another subtask from Task 8 was passed by 98% of the sample, and this was a double airplane with a horizontal projection ( ). Thus, a simple projection of an object along a vertical line, or the meeting of the two objects in space along a vertical or horizontal line were well within the capabilities of most 6-year-olds and even the majority of 5-year-olds. These accomplishments represent early manifestations of ability to project a straight line from a point of origin. The angle from which the projection was made may be important, because the results demonstrated that the vertical lines and the double horizontal lines were the easiest to produce.

The single horizontal line projection ( ) was not as readily achieved, however. Only 70% of the sample succeeded

in accurately producing this straight line trajectory. (This somewhat anomalous finding may be due to a sensori-motor factor having to do with moving a pencil from left to right, or to an ambiguous positioning of the airplane on our part.) The intersection of a horizontal with a vertical line ( ), on the other hand, was passed by 91% of the sample (This strengthens the liklihood that the horizontal line projection errors were anomalous.)

Single and double line projections from oblique orientations were more difficult. Between 80% and 84% of Ss achieved five of these trajectories, but only 69% was able to find the point of intersection between two oblique projective lines from the right ( ), and only 61% of Ss was able to produce an accurate straight trajectory for a single airplane from the right top ( ).

Spatial trajectories, therefore, can be successfully achieved by Ss as early as the 1st. grade, if the projections are vertical or horizontal. Oblique projections increase the difficulty of the task, suggesting that planning and producing oblique straight lines presents added difficulties.

The ability to construct straight lines with the use of discrete objects developed later, on the whole, than the ability to produce straight line trajectories with pencil and paper. For Task 11 (Construction of Straight Lines), Straight line 1, which was built parallel to the table, was passed by 62% of Ss. Straight line 2, which was built at an oblique angle of 45 degrees, was passed by 42%, and Straight line 3, which was built on the chord of a circle, by 37%. Thus, production of the two oblique straight lines was of approximate difficulty, with construction on the chord presenting more problems for a few Ss. Only by 3rd. grade do we find more than half of the Ss succeeding with the oblique straight lines.

The greater difficulty of the two oblique line constructions supports the earlier described progression from vertical and horizontal to oblique found with Task 8. Thus we begin to note some generality to the progression in straight line production from positions in space that lie at different points on the compass. The horizontal-vertical axes seem to be acquired first.

We note that construction of a straight line with the use of discrete materials is not limited by an inability to sequence or linearly arrange parts. This was never a problem for Ss at any age when performing on Task 8. Also, Table 13 shows that on Task 13, where beads were transformed from a circular to a linear array with order conserved, the large majority of Ss (97%) succeeded. However, it may be important to remember that there were "aids" to linear construction. The Ss were required to begin with a particular bead, and to string them sequentially onto a wire. Thus, the ordered arrangement of differently colored beads, wherein each bead was added to its proximate, was achievable by most 1st. grade children. Consequently, these data suggest that sequencing discrete objects on the basis of proximates appears during early school age, but is insufficient

for planning and constructing projective lines from a point of origin.

The fact that 89% of the sample succeeded in accurately anticipating the order with which beads would emerge from a tube in Task 13 tells us that ordering a few distinctive elements can be accomplished over brief intervals, which requires memory, even by a majority of 1st. grade children.

Recognition of perspectives from pictures (Task 9)* showed a progression of accuracy. The front view of most objects was identified by the largest number of Ss, followed by the side view of objects, and finally the rear view. Percentages of accurate recognition were as follows: front Cheese (95%), front Pig (94%), front Cat (84%), side Pig (91%), side Penguin (84%), side Cat (81%), side Cheese (81%), back Penguin (76%), back Cat (75%), back Cheese (70%). The front view of objects was the S's own view in all cases, since he faced each object. Thus, the egocentric view was most readily identified, with only the front Cat presenting difficultiies for more than a few Ss. However, as Ss were required to adopt a perspective other than their own momentary one, the task became more difficult. The 180-degree view proved to be the most difficult.

Awareness of the perspective of others (Task 10) was not included in the scalogram analysis because of the low intercorrelations among the four perspective views.

Coordination of Perspectives (Task 12) proved to be a very demanding problem, requiring an advanced understanding of perspectival relationships. The ability to construct a replica of what a viewer sees of the barnyard when removed from the S by a rotation of 90 degrees was limited in the age-range studied. Only 22% of the sample passed this subtask. Even more difficult was a construction of how the barnyard would appear with a rotation of 180 degrees. No more than 17% of the sample passed this subtask.

These data on the perspective tasks demonstrate an interesting progression in the growing awareness of projective space. First, the average child in our sample was able to project a straight line over a reasonably short distance, especially when the projection was along the vertical and horizontal axes. Only later were Ss as successful in projecting straight lines from oblique points of origin. Recognizing how something looks from an angle other than one's own involves being able to imaginally adopt another point in space and project an imaginary straight line from that point. As we saw, better than four-fifths of the sample

---

* Only 10 judgements were used for scaling in order to use only those perspectives that were consistently presented: front, side, back.

achieved this degree of projective awareness when judging a 90-degree rotation.

However, Construction of Straight Lines (Task 11) from points in space with discrete materials and across distances of 20 in. seems to require operations of planning and projecting (such as sighting) that did not appear in our sample until after straight line trajectories could be anticipated and other perspectives recognized in drawings. And, as mentioned, organizing a series of varied materials to render their appearances from a position other than ego's, was the most difficult projective problem; one that only about one-fifth of the sample could properly solve.

Conservation and Measurement

We were interested in determining whether Conservation of Length (Task 4), the awareness that the length of a path is unchanged by its shape, precedes or follows ability to measure length (Task 5). For the entire sample, 75% of S accurately judged which of the lines in set #2 was the longer and 70% of the Ss were accurate with regard to set #1. Conseration of length, however, was passed by only 50% of the sample. Therefore, one cannot draw clearcut inferences about an influence of conservation upon measurement, or of measurement upon conservation, from these data. The finding that measurement preceded conservation, for more Ss is suggestive, and warrants further study of this relationship. In addition, it is important to note that correct estimation of line lengths for sets #1 and #2 reflected only a beginning understanding of measurement. With sets #3 and #4 a further level of measurement knowledge was required, since S had to grasp the means of equating a smaller and a larger measuring device. We found that only 42% understood the relationship. Also, when it came to truly accurate, rather than approximate, use of the measures, only 33% of Ss were truly accurate. These findings suggest that a form of "intuitive measurement" based on perception of the linear length, together with an approximate measuring and counting-off procedure, preceded conservation of length; however, a fuller awareness of measurement often was not achieved until the 3rd. or even 4th grades - a time when the large majority had learned to conserve length.

Two additional analyses were made of the relationship between performance on Measurement of Length and Conservation of Length: (1) a product-moment correlation test, and (2) a comparison of individual S's performance changes across sessions on the two tasks. (1) Correlation of Performance for Measurement of Length and Conservation of Length. A correlation of scores on the two tasks was carried out for each grade across the three sessions. The correlations are presented in Table 15.

Only at two points was the correlation between performance on the two tasks significant - for Kindergarten at Session 3 and for 3rd. grade at Session 1.

(2) Relative Change Across Sessions - No clearcut pattern emerged from this comparison. Only in a small number of cases was a score of one task (e.g., Conservation of Length) at the time of Session I or Session II predictive of change on the second task (Measurement of Length) at a later session. Thus, a "leader-follow" relationship was not evident.

Design Copying (Task 2) and Block Design (Task 3)

These tasks assessed several capacities, chiefly the ability to analyse figural and pattern relations, and to use these for guiding perceptual-motor organization. Block Design requires a greater degree of perceptual analysis, whereas Design Copying places heavier demands on the act of reproduction. For purposes of determining scalability as part of the 69 subtasks, each of the eight designs that Ss copied was scored as 0, 1 or 2 for topogical accuracy and as 0, 1 or 2 for Euclidean accuracy. This seemed to us a useful way of classfying performance according to dimensions that apply to all the designs, and that have some conceptual basis (cf. Piaget and Inhelder, 1956). To make topologically accurate reproductions, a S had to preserve the open or bounded character of a figure, properly distinguish elements as lying within or outside the principal figure, and correctly render overlapping, intertwining, contact and masking relationships. To score as correct on Euclidean grounds, a S's copy had to preserve the figural proportions, angles, and lengths of lines. For each dimension of classification, a score of 0 indicated failure, 1 indicated partial accuracy. and 2 a good rendition. A dichotomization was necessary for scalogram analysis, and a score of 2 was considered passing, while 0 or 1 were considered failing.

Using this basis of classification, we see (Table 14) that the majority of our Ss were able to render the topological properties of Designs 1, 2, 3, 5 and 7. These, chiefly involved an appreciation of the closed character of the figures, as well as overlapping for Design 7, and inside vs. outside the boundary for Design 5. At least 95% of the sample was capable of preserving these topological properties. Much more difficult topological properties were presented by Designs 4, 6, and 8. With Design 4, most Ss achieved the enclosed relationship, but many failed to produce a circle that contacted the triangle at three points. Only 44% of the sample was able to render correctly the masking relationships for Design 8, and only 20% could handle the interlocking (a form of masking) relationship of Design 6. These results contrast sharply with the relative success Ss had in reproducing overlapping without masking (Design 7).

Euclidean features were difficult for a majority of the Ss. Design 2, the triangle, was the Euclidean shape passed by the largest number of Ss (62)% . Only by 2nd. Grade did a majority of Ss demonstrate an accurate grasp of proportions and angles. Even more difficult to render were the rhombus (36%) and the overlapping elipses (33%). The latter, Design 7, produced many errors of proportion, and place of overlap. Similarly, errors of proportion and distance were common for the case of Design 5. Design 1 produced many of the errors typically found in copying a square, such as rounding of corners, failure to join lines and poor

proportions, plus the added difficulty of producing the diagonal. Therefore, although 95% of the sample succeeded in preserving the topological character of the figure, only 30% adequately rendered its geometrical properties. Designs 4, 6 and 8 proved to be very difficult for children in the age-range studied. Design 6 produced as many Euclidean as topological problems for our Ss. Sizes were changed and the circular character of the rings distorted. It may be that the topological demands posed by intertwining rings were so great that they completely befuddled most Ss. Few Ss below the 4th grade had much success with this design. Design 4 also suffered geometrically because of the trouble most Ss had in producing a circle within the confines of the triangle. The circle was often distorted by stretching or compressing, and the equilateral nature of the triangle lost. The degree of planning required, as well as perceptual-motor control, was too great for most Ss, and only 19% were accurate.

It seems as if the same general difficulty was encountered in reproducing Design 8. The Euclidean features, especially right angles for squares and rectangle, should not have presented such considerable difficulties of themselves; however, when included along with the topological masking arrangement, Euclidean features were usually distorted. Thus, the greater complexity of some designs created a part-whole relationship that oftentimes made reproduction of the part more difficult than it would have been when presented by itself. This might suggest that for the younger Ss, in particular, a design that is more complex either geometrically or topologically affects perceptual analysis. There may be problems of decentering, or momentarily abstracting a part from the whole, while still maintaining some imaginal or planned link to the whole. It may well be that part-whole coordination, the capacity to mentally represent interrelationships of parts and wholes, and planfulness, will prove to be important components of a wide range of spatial performance.

Block Designs (Task 3) also require perceptual analysis - to an even greater extent than Design Copying. The capacity to analyse a gestalt and recompose it with three dimensional blocks that are themselves patterened differently on each side, requires considerable skill. But, despite the widespread use of this WISC subtask, we know very little about the processes on which success depends. As might be expected, four-block patterns of the type depicted by Block Designs A, B, and C, were not difficult for most 1st. graders. Most Ss passing A, B, and C were also successful in preserving the topological features of enclosure and adjacency in Design Copies 1, 2, 3, 5 and 7. But, whereas 94% of Ss passed Block Design C, the next one in the series, Block Design 1, was passed by only 66% of Ss. Subjects in 1st. grade found this design very difficult. Constructing a white triangle against a red backdrop requires using blocks such that half of each block must serve as figure while the other half serves as ground. Thus, Ss had to realize that the split blocks may be used to represent both figure and ground. The figural space and the discrete object space occupied by each block were not isomorphic. It is instructive

to observe children attempting to construct this white triangle with block surfaces that are totally white. They show an inability to divide space on the basis of color, and create a geometric shape with half of that space. Block Designs 2, 3 and 4 also present this requirement, but compound it by calling for more than one figural composition within the design. Our findings were that Block Designs 3 and 4 are of equal difficulty. They are symmetrical patterns, whereas Block Design 2 is asymmetrical, and was passed by fewer Ss. The seven-block designs were also easier when the pattern was symmetrical (e.g., Block Design 5) rather than asymmetrical. Children who could properly synthesize the elements of asymmetrical Block Designs 6 and 7 were usually also capable of coordinating difficult topological and Euclidean features in their design copies (Task 2), and of coordinating perspectives (Task 12). These were the highest reaches of spatial ability assessed in this study, and only some 4th grade Ss were capable of them.

Awareness of the Vertical and Horizontal Axes

Awareness of the vertical projection of trees growing on a hillside means that either through recognition or construction the S should acknowledge that trees grow perpendicular to the ground rather than to the slopes of the hill. Our findings suggest that this is probably not a unitary ability, one in which a single measure predicts all other measures. Instead, recognition in a picture of the proper positioning of trees on a hillside was demonstrated by most Ss (92%) at all ages, whereas awareness of the vertical shown by proper planting of trees on a model hillside was passed by only 73% of the sample. And, awareness of the vertical as demonstrated in drawings produced by the children was present in only 62% of cases. Thus, planting and drawing were less advanced than recognition. Recognition might be the best index of understanding in this situation, because both planting and drawing errors could result from poor sensori-motor performance. However, it is just as likely that the recognition procedure provides the S with comparative information (a correct picture alongside an incorrect picture) that assists his judgement. Lacking this additional information, Ss must "construct" their action in the face of competing forces (the slope of the hill), and this may account for the added difficulty. Which one of these interpretations is correct cannot be decided by this study.

Awareness of the invariant horizontal plane of a liquid in a container proved to be difficult for most Ss. Performance for the 90 degree tilt was best, as expected, since the horizontal level is parallel to the sides of the jar and the table in this position. Yet, only 66% of Ss were correct even with this angle. Many young children drew the water level parallel to the base of the container. Awareness of the horizontality of the water level at 315, 45 and 135 degrees was demonstrated by fewer than one-third of the sample. There were more errors at 135 degrees than at any other position. I believe we can say that even for children of the 4th grade, the invariant level of liquid in a container is not generally understood. No more than 25% of Ss fully grasped this fact.

The strong pull created by the container's position demonstrates the continuing impact of perceptual field effects on the level of spatial cognition. We were not altogether surprised to find that Awareness of the Horizontal was achieved, in the main, by Ss who had succeeded in sufficiently decentering to adopt other perspectives (Task 12), and could succeed in analysing the parts of complex figures so as to successfully reproduce them in their own drawings (Task 2: Designs 4, 6 and 8) and figural constructions (Task 3: Block Designs 5, 6 and 7).

DISCUSSION

The findings of this investigation have provided a number of leads regarding the growth of spatial understanding, and have also, at a number of points, served to corroborate the results of other investigators. Moreover, as all research should be, this study has been heuristic; it has posed further, but sharper questions, and suggested future lines of investigation. One must be cautious in using these findings for suggesting educational policy. All too frequently, policy recommendations are made with insufficient empirical data to back them. The education of the child, as growth itself, is an organic process in which a change in one area can produce unforseen changes in another.

Mastery of Projective, Euclidean and Topological Relations. - Our data clearly indicate that at least with Ss of the type we studied, a number of important aspects of spatial awareness have been internalized by kindergarten age. This means, of course, that the child can do more than effectively move in space; he can apply his knowledge of spatial relations to the solution of reasonably novel problems. With regard to understanding projective properties of space, the majority of kindergarten Ss were able to imagine and produce straight line trajectories if these trajectories were in the horizontal and vertical planes. Straight line trajectories were projected more accurately at older ages, of course, but even the kindergarten Ss were successful for horizontal and vertical planes. On the other hand, projections of straight lines for oblique orientations proved to be considerably more difficult. Therefore, the ability to produce projective straight lines is certainly manifest by kindergarten age, but is very much dependent on the axes of space in which projection occurs.

When we consider the performance of Ss on a second task of projective understanding, the Construction of Straight Lines, we found that this task was considerably more difficult, but that the axis of space in which a projective line was produced, also influenced effectiveness. In this case too, obliques were more difficult than the horizontal construction, and the Ss who passed the oblique projections at any of the three sessions were typically 3rd. grade and 4th. grade children. Future research will be needed to clearly specify why young children were capable of producing straight lines in one case, but not the other. Two factors may be important, and will be studied. One is the size of the field over which lines are projected, and the other is the facto. of discrete vs. continuous

line formation. Building a straight fence with discrete materials, which was the situation for Construction of Straight Lines, is likely to pose problems of sighting, spacing, maintenance of direction, and intention, that were not present to nearly the same degree when producing Straight Line Trajectories. In some respects, these findings are consistent with those of Piaget and Inhelder (1956); they certainly confirm their results for Construction of Straight Lines. However, our finding that even preschool children understand some of the properties of projective space, in certain situations, does not accord with Piaget and Inhelder's conclusions.

If we turn next to other examples of understanding projective space, namely, a grasp of perspective, and an awareness of the different perspectives available to a viewer from different positions in space, we find further evidence for progressions. However, here the progression appears to be one that begins with the ability to recognize the significance of location in space for what one perceives, and moves later to an ability to mentally rotate objects in space so as to depict a scene from another's perspective. Our results for two tasks, Recognition of Perspectives and Representation of Perspectives, indicate that for more than 50% of the scenes, 1st. graders were able to represent what an individual sees from a given position in space. Taking account of the fact that this task suffered from a degree of built-in ambiguity, we still noted a definite improvement across ages, with steady improvements being made by each later grade. By 2nd grade, perspectives were accurately recognized in 89% of cases.

Thus, perspective awareness as measured by understanding of the view available to an observer from his location, is partially in evidence by early school age. Some researchers using quite different procedures (Flavell, 1968; Shantz and Smock, 1966) have concluded that perspective awareness of a simpler form is present even younger. However, the ability to coordinate perspectives, to mentally rotate a scene, and to maintain the projective relations of left and right while making these imaginal transformations, truly involves advanced spatial skills. From our analyses, and those of a recent doctoral dissertation (Cousins, 1972), the Coordination of Perspectives task makes these kinds of demands of the S, and few children below ages ten of eleven have mastered them.

We were impressed with the finding that simple topological spatial properties such as proximity, order and enclosure were commonly found among even some of our youngest Ss. Beads were transformed from circular to linear order by the majority of even kindergarten Ss at the time of Session II. Successful completion of this task required the preservation of contiguously ordered elements, and this was accomplished early. Even the reversal of a linear order was achieved by a sizeable number of Ss during kindergarten. Here too, performing with beads involved only the ordering of proximate elements, and demanded no projective ability (as contrasted with projective ability required when constructing straight lines with discrete elements).

Similarly, even kindergarten Ss were successful in copying designs that were bounded when scored for this topological property. Enclosed figures were typically drawn as such, parts within a design (e.g., a diagonal within a square) were usually kept where they belonged. Overlapping proved to be more variable, and was rendered regularly by younger Ss when no masking was involved. However, where masking was present in a design, proper representation of overlapping and inter-position proved to be considerably more difficult. This was clearly the case for Designs 6 and 8. It is interesting to consider the extent to which masking and interposition present problems of rendering three-dimensionality, and whether this is responsible for increasing the difficulty of these designs. In a truly three-dimensional display, masking and interposition would be projective features of objects.

The Euclidean properties of the designs were mastered by Ss who had already shown that they could deal with the simpler topological properties. By the reasonably strict criteria that we used for angles, lengths of line, parallelility, and points of joining, these Euclidean properties certainly followed the topological ones and were seldom found in the copies of kindergarten or 1st. grade children. Executing the Euclidean features of figures such as a diagnol, a transverse, or pair of straight oblique lines, involves considerable planning and ability to take account of projective-type features (i.e., a straight line from a point of origin). We would agree with Vereecken (1961) that considerable skill development is needed before the cognitive planning can result in an effective perceptual-motor product. Children in the 1st. grade were sometimes capable of rendering parts of a figure correctly, but usually failed when it came to fully coordinating the sides and angles of a Euclidean design. It is also of interest that designs containing difficult topological properties (Designs 4, 6 and 8) produced Euclidean errors that might have been avoided if the topological demands of the designs had been less. Therefore, we have additional evidence of the requirement that a design be planned and the parts mentally coordinated prior to drawing, as well as during the overt activity, in order to produce a good product.

Asymmetrical Block Designs proved to be very difficult for our sample, and only 4th. graders had much success with them. In this task, a S must select colors and shapes, and imagine the outcomes of subgroupings - and perhaps, the coordination of subgroupings - in order to proceed. The problem is not one of executing an angle or maintaining a straight line, as was true in copying designs with a pencil, but of visualizing how to use the parts that are given. Thus, here too, processes of visual analysis and structuring were needed. Moreover, Euclidean and topological properties had to be appreciated. Only a few Ss in the age-range studied possessed the spatial abilities required by the higher level Block Designs.

Awareness of Vertical and Horizontal. - In line with their theoretical position, Piaget and Inhelder (1956) have claimed that acquisition of vertical and horizontal coordinates of space appear at the same time. The findings of

this study provide evidence of the earlier acquisition of the vertical than the horizontal coordinate, at least in terms of how they were measured here, or by Piaget and Inhelder. We are tempted to think that the power of the perceptual frame of reference may influence the success children have in displaying an understanding of either axis. The perceptual impact of the tilted container on the judgment of horizontal water level seems greater than the effect of oblique hillsides on the judgment of the vertical. The liquid in the container is completely "imprisoned" by the walls of the jar, which produces a powerful effect that is difficult to overcome. Planting trees on a hill, however, is influenced only by the oblique lines of the hillside, a pair of lines external to the planted trees. In this case, it should b possible to make better use of the horizontal-vertical coordinates of the page, or of the mountain and tabletop, as larger external reference frameworks. Therefore, Piaget and Inhelder may be correct in saying that developments in the understanding of horizontal and vertical coordinates appear synchronously and culminate in the completion of a coordinate system. Yet, we would withhold further acceptance of this idea until the assessment of vertical and horizontal coordinates is more perfectly controlled.

Rates of Change. - In the case of most tasks studied, improvement was continuous, with more Ss showing higher level performance at each successive session. For seven tasks (Tasks 1, 3, 4, 5, 9, 12 & 13) improvements with each session were statistically significant, indicating that sizeable changes had occurred over periods of around six months. Most of the remaining tasks showed significant improvements between Sessions I and III

Sex Differences. - A curious pattern of sex differences appeared in our findings. Where significant sex differences were found, which was the case for five tasks (Task 3, 7, 8, 9, & 11), boys were in advance of girls. In the case of three of these tasks, the large sex differences appeared during 3rd. grade. It would be a conceptual "tour de force" to attempt an explanation of why sex differences occurred where they did, and we will not risk one here. Perhaps the finding that sex effects, where found, increased with age, should be underscored. If differential socialization of boys and girls, or sex-linked variations in activities, are responsible for the sex differences, we might expect these factors to exert their influence more clearly with increasing age. This way of thinking would certainly be consistent with our findings.

Educational Implications. - As mentioned earlier, policy matters in education are best approached cautiously, and the results of any investigation need to be cross-validated in order to insure their generalizability. With these cautions in mind, it seems to us that a few suggestions may be made. We began by suggesting that spatial thinking, especially the ability to make spatial rotations and transformations, is less than a fluid process for many youngsters and adults. Yet, we were able to see considerable progress in the development of spatial skills between the ages of 5 and 8. However, it does not appear that children are well-practised in the use of spatial skills. Understanding of the oblique orientations of lines or objects in

space lags behind a grasp of lines and objects in the vertical and horizontal planes. More could be done to incourage the imaginal and overt production of obliques and diagonals in space. Projections of lines in space, as well as the intersection of lines in different fields (e.g., a circle or parallelogram) could be practiced with both two-dimensional and three-dimensional layouts.

Even more important may be the encouragement of spatial knowledge about rotations. The ability to find points of reference in a scene or in a figure, and to imagine the outcomes of various rotations, seems to us to be a high order spatial ability that is necessary for much advanced thinking in science, mathematics and related applied fields. However, our data suggest that these abilities develop slowly in the person. The rate at which they develop is, of course, less important than whether they appear at all sometime before maturity. However, growth in other areas, particularly technical ~~fields~~, may proceed more effectively with than without these spatial tools. Therefore, we would be interested in seeing future research that attempts to train spatial awareness and representation, in particular those forms that deal with projective relations in complex arrangements. Any training program that could bolster the average student's ability to learn mathematics and science would be of great value, and would provide an entrance to regions of knowledge that are currently closed to many.

Although it is very difficult to interpret the several significant sex differences that were found, they should not be ignored. More research will be needed to make sense of them, but the effort may be worthwhile if it points to differences of approach or cognitive styles in sizeable numbers of boys and girls.

The importance of providing training in spatial awareness, in mentally rotating and transforming events, and in developing a coordinate system, will not appear obvious to many. However, at the conclusion of this research, we remain convinced that these abilities can be advanced by proper education, and that the benefits to be obtained by such an undertaking would repay the effort required.

REFERENCES

1. Cassirer, E. Philosophy of Symbolic Forms. Vols. 1 and 3. New Haven: Yale University Press, 1957.

2. Edwards, A.L. Techniques of Attitude Scale Construction. New York: Appleton, 1957.

3. Flavell, J.H. The Development of Role-Taking and Communication Skills in Children. New York: Wiley, 1968.

4. Kant, I. Critique of Pure Reason. Rev. ed. New York: Colonial Press, 1900.

5. Laurendeau, M. and Pinard, A. The Development of the Concept of Space in the Child. New York: International Universities Press, 1970.

6. Macfarlane-Smith, I. Spatial Ability: Its Educational and Social Significance. San Diego: R.R. Knapp, 1964.

7. Piaget, J. The Construction of Reality in the Child. New York: Basic Books, 1954.

8. Piaget, J. and Inhelder, B. The Child's Conception of Space. London: Routledge, 1956.

9. Shantz, C.U., and Smock, C.D. Development of distance conservation and the spatial coordinate system. Child Development, 1966, 37, 943-948.

10. Street, R.F. A Gestalt Completion Test. New York: Columbia University, 1931.

11. Wechsler, D. Wechsler Intelligence Scale for Children. New York: Psychological Corporation, 1949.

12. Werner, H. Comparative Psychology of Mental Development. New York: International Universities Press, 1948.

13. Winer, B.J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1962.

14. Vereecken, P. Spatial Development. Groningen: J.B. Wolters, 1961.

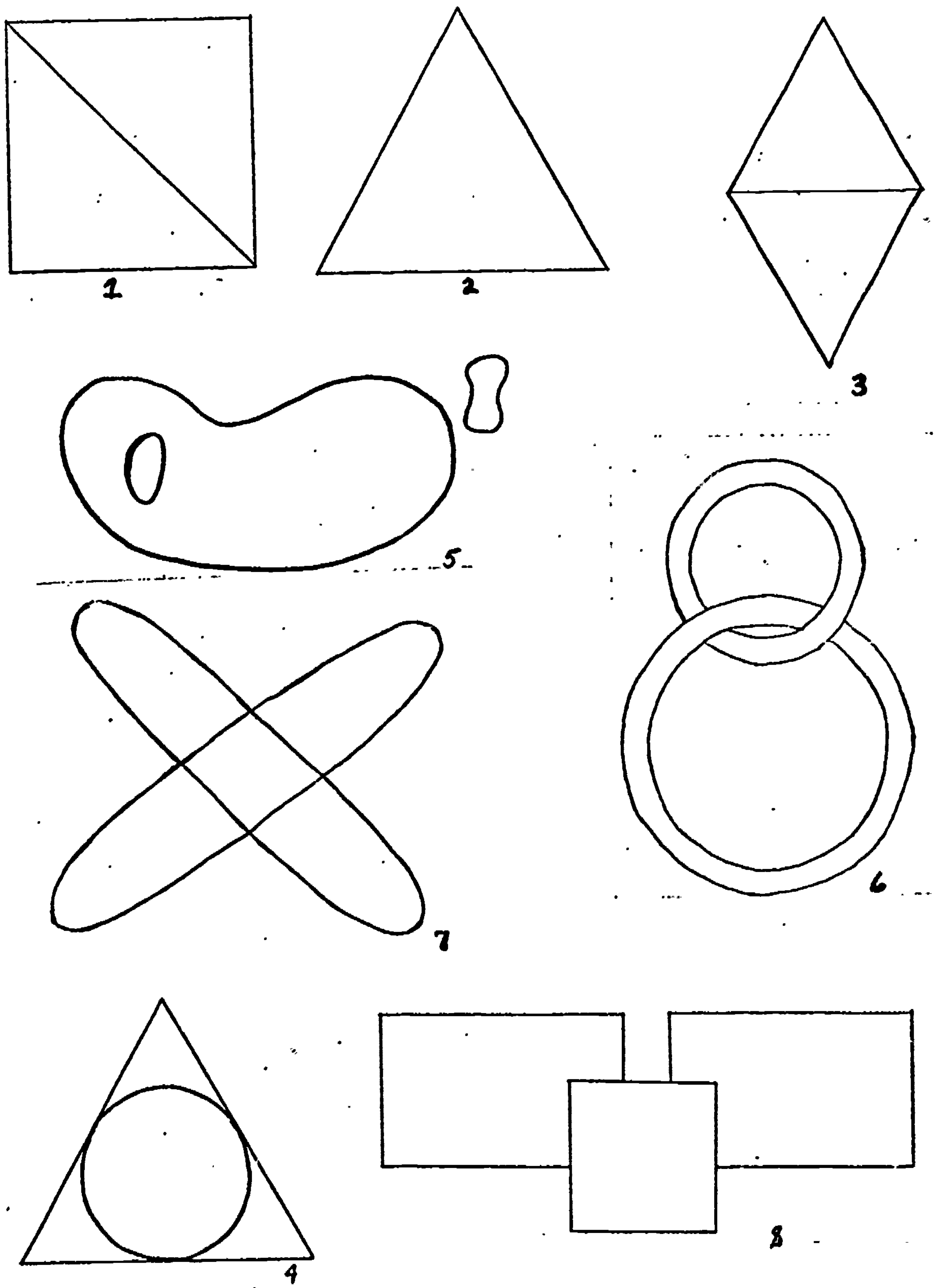

Figure 1.- Standard designs used in Design Copying.

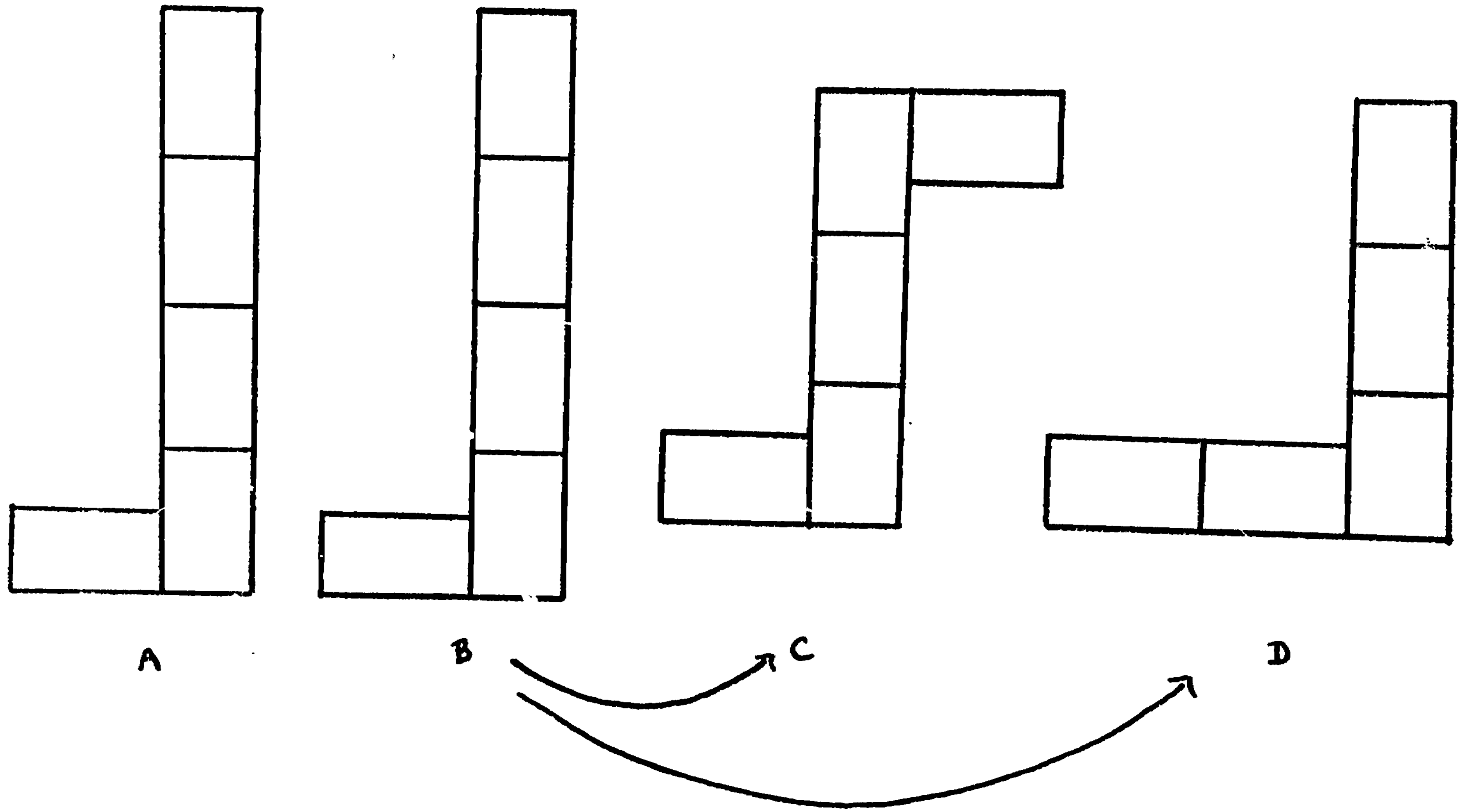

Figure 2.- "Road" changes used for studying conservation of _ength.

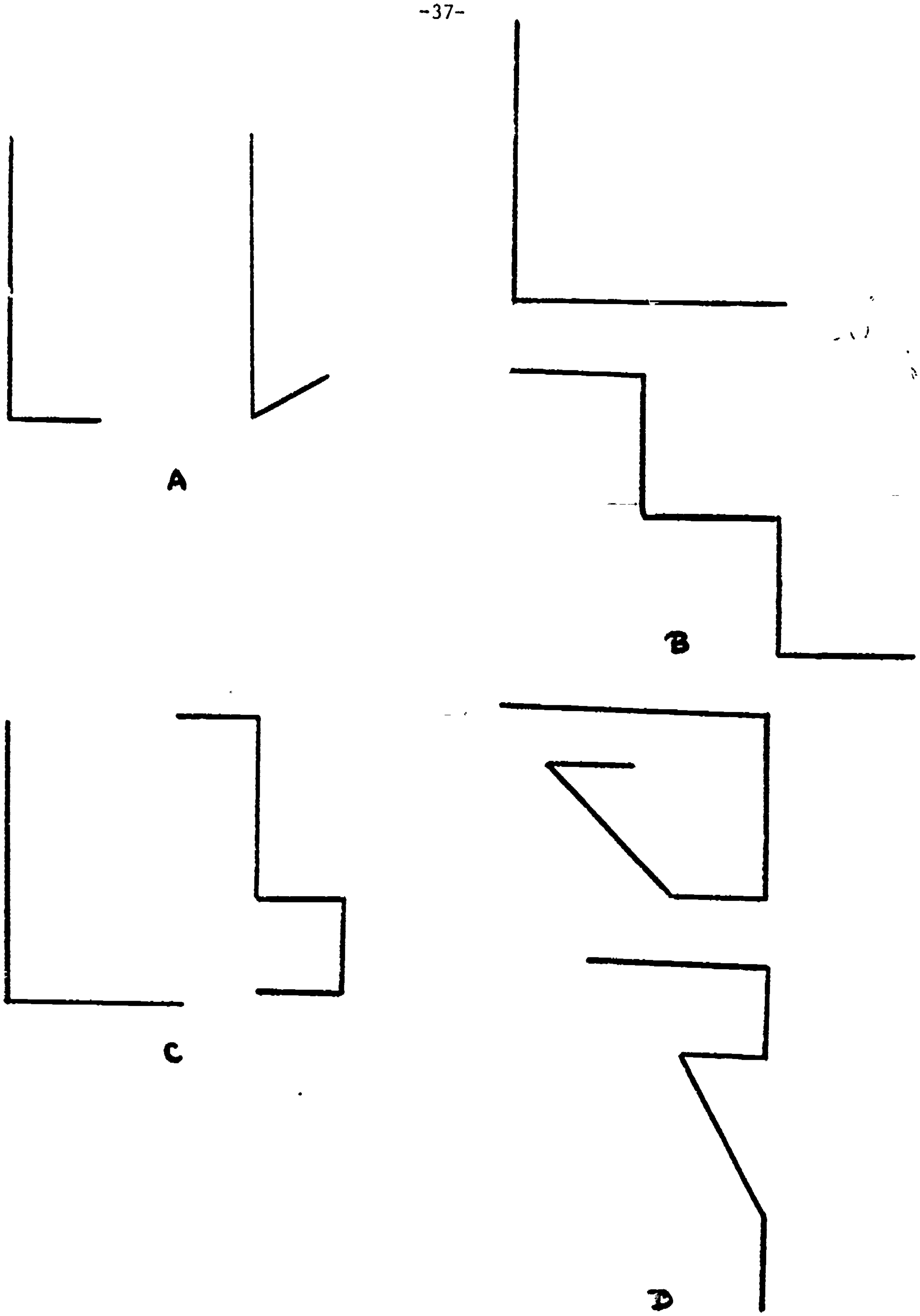

Figure 3.- Line pairs used for measuring length.

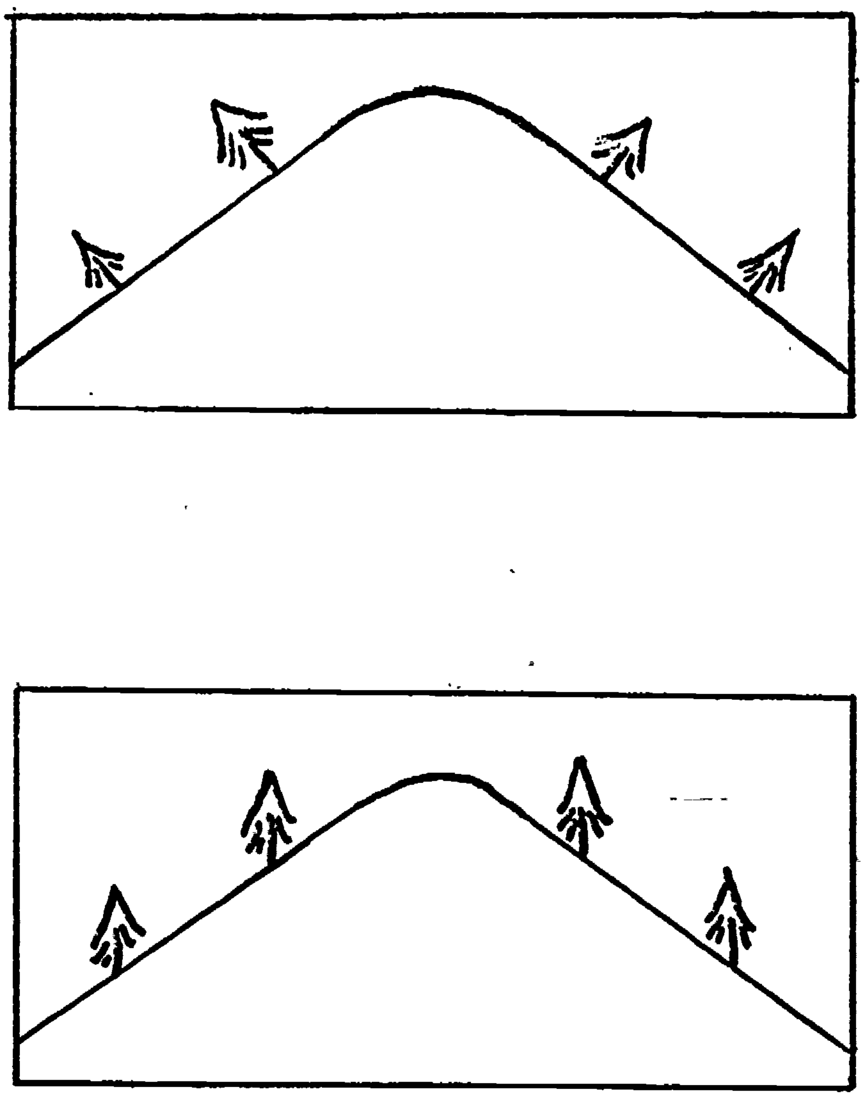

Figure 4.- Two drawings of how trees might grow on a mountainside.

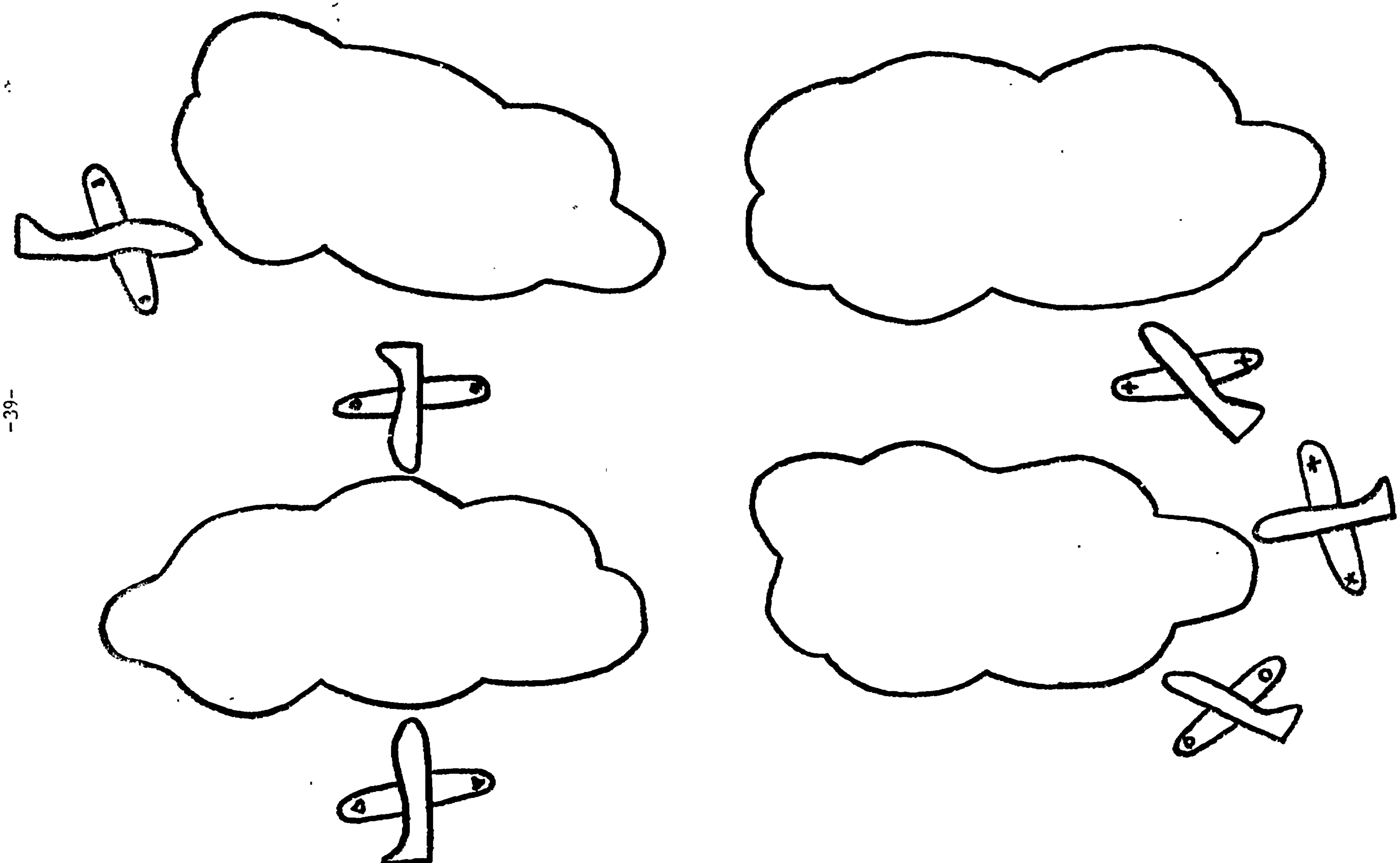

Figure 5.- Examples of single-and double airplanes entering clouds.

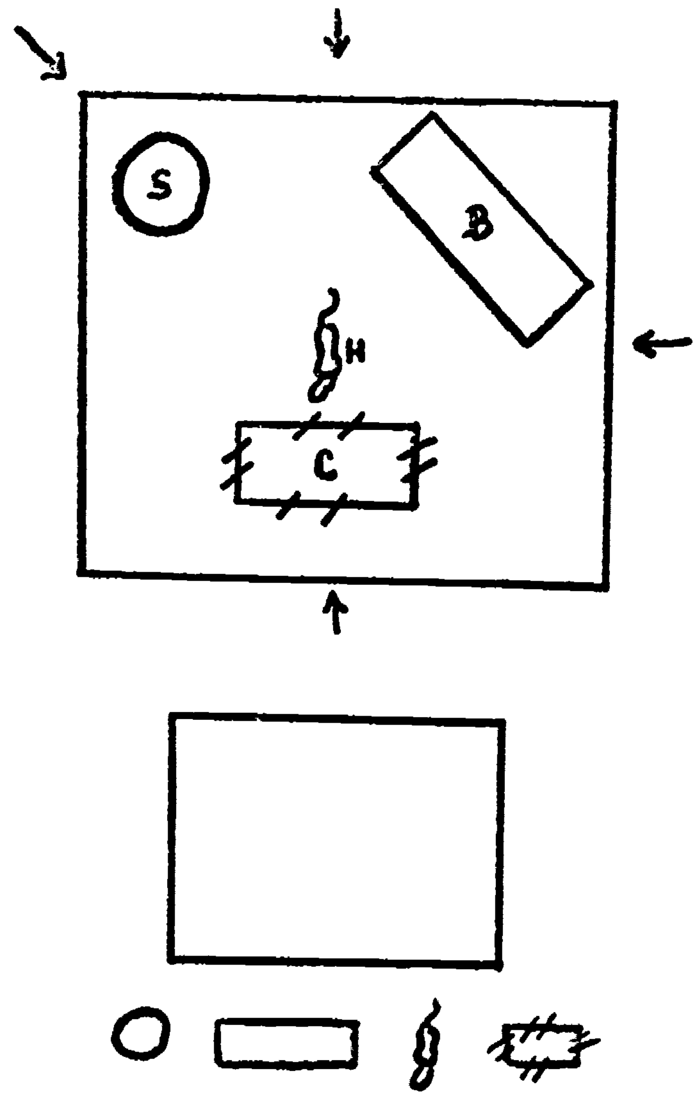

Figure 6.- "Birdseye" view of model barnyard and subject's equivalent construction materials.

Table 1a

Recognition of Incomplete Pictures (Task #1): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kdgtn.	Females	14.38	2.98	19.25	4.99	24.00	3.50	20.40	6.54
	Males	15.36	4.31	19.46	3.99	19.27	6.59	22.00	4.85
	Total	14.95	3.62	19.37	4.48	21.26	5.43	21.20	5.49
1st.	Females	19.00	3.62	25.82	5.68	26.73	6.77	22.80	5.89
	Males	19.09	4.96	24.73	6.35	25.09	7.66	24.20	3.27
	Total	19.05	4.24	25.27	5.77	25.91	7.10	23.50	4.55
3rd.	Females	22.75	4.71	30.33	6.33	32.00	6.60	25.40	4.88
	Males	21.27	3.91	29.45	4.96	27.82	4.90	23.80	3.63
	Total	22.04	4.28	29.91	5.54	30.00	6.03	24.60	4.14

Table 1b

Recognition of Incomplete Pictures: Newman-Keuls Comparisons (Grade & Session Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.		**	**
1st.			**

	Session 1	Session 2	Session 3
Session 1		**	**
Session 2			

* $p < .05$
** $p < .01$

Table 2a

Design Copying (Task #2) : Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kdgtn.	Females	2.78	0.89	3.22	0.92	3.28	0.87	3.70	0.69
	Males	2.86	0.92	3.08	0.80	3.19	0.81	3.32	0.69
	Total	2.82	0.90	3.16	0.87	3.24	0.85	3.51	0.71
1st.	Females	3.49	0.76	3.76	0.83	3.77	0.72	3.62	0.87
	Males	3.51	0.79	3.88	0.74	3.83	0.82	4.22	0.77
	Total	3.50	0.77	3.82	0.79	3.80	0.77	3.92	0.87
3rd.	Females	4.22	0.76	4.28	0.74	4.20	0.76	4.45	0.75
	Males	4.44	0.65	4.65	0.56	4.27	0.67	4.42	0.68
	Total	4.33	0.71	4.47	0.68	4.24	0.72	4.44	0.71

Table 2b

Design Copying: Newman-Keuls Comparisons (Grade, Session, & Design Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.		**	**
1st.			**
3rd.			

	Session 1	Session 2	Session 3
Session 1			*
Session 2			

Designs	8	7	5	3	1	4	2
6	**	**	**	**	**	**	**
8			**	**	**	**	**
7				**	**	**	**
5						**	**
3						*	**
1						*	**
4							**

* $p < .05$

** $p < .01$

Table 3a

Block Design (Task #3): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Females	4.36	3.78	6.91	3.62	9.27	5.88	5.60	2.97
Kdgtn.	Males	4.50	2.78	7.00	3.55	6.38	2.00	12.20	7.89
	Total	4.42	3.31	6.95	3.49	8.05	4.79	8.90	6.61
	Females	7.82	5.10	11.64	5.85	11.73	6.86	12.40	10.78
1st.	Males	7.09	3.94	13.09	7.65	17.09	8.35	23.20	12.19
	Total	7.45	4.46	12.36	6.69	14.41	7.94	17.80	12.26
	Females	13.91	7.11	15.82	9.63	21.27	11.31	18.20	7.66
3rd.	Males	21.42	8.31	26.25	10.20	33.33	10.98	26.60	11.33
	Total	17.83	8.49	21.26	11.07	27.57	12.50	22.40	10.14

Table 3b

Block Design: Newman-Keuls Comparisons (Grade and Session Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.		*	**
1st.			**

	Session 1	Session 2	Session 3
Session 1		**	**
Session 2			**

* $p < .05$
** $p < .01$

Table 4a

Conservation of Length (Task #4): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Females	0.00	0.00	0.27	0.90	0.00	0.00	1.80	1.64
Kdgtn.	Males	0.25	0.71	0.25	0.71	0.50	1.07	0.60	1.34
	Total	0.11	0.46	0.26	0.81	0.21	0.71	1.20	1.55
	Females	0.00	0.00	0.55	1.21	1.23	1.51	1.80	1.64
1st.	Males	0.18	0.40	0.55	1.21	1.36	1.57	2.40	1.34
	Total	0.09	0.29	0.55	1.21	1.23	1.51	2.10	1.45
	Females	1.27	1.49	2.46	1.18	2.73	0.90	2.80	0.45
3rd.	Males	2.42	1.16	2.83	0.58	3.00	0.00	3.00	0.00
	Total	1.87	1.42	2.65	0.94	2.87	0.63	2.90	0.32

Table 4b

Conservation of Length: Newman-Keuls Comparisons (Grade & Session Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.			**
1st.			**

	Session 1	Session 2	Session 3
Session 1		**	**
Session 2			*

* $p < .05$
** $p < .01$

Table 5a

Measurement of Length (Task #5): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Females	1.36	1.12	2.00	1.55	2.18	1.54	2.40	3.29
Kdgtn.	Males	1.12	1.55	1.00	1.07	2.12	2.36	2.20	2.28
	Total	1.26	1.28	1.58	1.43	2.16	1.86	2.30	2.67
	Females	1.00	0.63	3.46	2.34	3.73	2.33	3.00	1.87
1st.	Males	1.82	1.47	2.82	1.40	4.09	2.77	5.80	3.35
	Total	1.41	1.18	3.14	1.10	3.91	2.50	4.40	2.95
	Females	4.54	2.58	5.54	2.07	6.73	1.79	5.80	2.17
3rd.	Males	6.67	2.27	7.08	2.07	7.83	0.39	6.80	1.79
	Total	5.65	2.60	6.35	2.17	7.30	1.36	6.30	1.95

Table 5b

Measurement of Length: Newman-Keuls Comparisons (Grade and Session Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.		**	**
1st.			**

	Session 1	Session 2	Session 3
Session 1		*	**
Session 2			*

* $p < .05$

** $p < .01$

Table 6a
Awareness of the Vertical (Task #6): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Females	0.79	0.96	1.00	0.97	1.09	0.95	0.93	1.03
Kdgtn.	Males	0.79	0.98	1.12	0.99	1.04	1.00	1.40	0.91
	Total	0.79	0.96	1.05	0.97	1.07	0.96	1.17	0.99
	Females	1.15	0.97	1.58	0.75	1.58	0.79	1.07	1.03
1st.	Males	0.88	0.99	1.45	0.90	1.88	0.42	2.00	0.00
	Total	1.02	0.98	1.52	0.83	1.73	0.65	1.53	0.86
	Females	1.79	0.54	1.85	0.51	1.70	0.68	1.80	0.56
3rd.	Males	1.89	0.47	2.00	0.00	2.00	0.00	1.33	0.98
	Total	1.84	0.50	1.93	0.36	1.86	0.49	1.57	0.82

Table 6b
Awareness of the Vertical: Newman-Keuls Comparisons (Grade, Session & Task Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.		**	**
1st.			**

	Session 1	Session 2	Session 3
Session 1		**	**
Session 2			

	Drawing	Planting	Recognition
Drawing			**
Planting			**

* $p < .05$
** $p < .01$

Table 7a

Awareness of the Horizontal (Task #7): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kdgtn.	Females	0.18	0.40	0.82	1.54	1.27	1.79	1.80	2.49
	Males	0.38	0.74	1.25	1.49	1.00	1.07	1.80	2.49
	Total	0.26	0.56	1.00	1.49	1.16	1.50	1.80	2.35
1st.	Females	1.82	1.47	1.18	1.40	1.64	1.21	1.80	2.05
	Males	1.09	1.45	2.55	1.63	3.64	2.29	3.80	3.11
	Total	1.45	1.47	1.86	1.64	2.64	2.06	2.80	2.70
3rd.	Females	2.27	2.33	4.36	3.23	4.00	2.53	3.80	1.79
	Males	5.50	1.98	6.92	1.56	7.25	1.60	4.80	2.59
	Total	3.96	2.67	5.70	2.77	5.70	2.64	4.30	2.16

Table 7b

Awareness of the Horizontal: Newman-Keuls Comparisons (Grade, Session, and Angle Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.		**	**
1st.			**

	Session 1	Session 2	Session 3
Session 1		**	**
Session 2			

Angle	135°	315°	45°	90°
135°			**	**
315°				**
45°				**

* p .05

** p .01

Table 8a

Awareness of Spatial Trajectory (Task #8): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Females	7.50	3.14	8.32	2.51	9.82	3.22	7.50	2.01
Kdgtn.	Males	9.94	2.79	10.25	2.84	10.31	2.60	8.60	2.68
	Total	8.53	3.20	9.13	2.79	10.03	2.95	8.05	2.37
	Females	9.36	2.52	10.27	2.43	11.00	3.12	8.60	2.55
1st.	Males	10.77	2.51	12.45	2.84	11.68	2.55	10.90	1.29
	Total	10.07	2.58	11.36	2.84	11.34	2.84	9.75	2.29
	Females	13.27	2.14	13.09	2.27	12.18	2.68	10.60	0.97
3rd.	Males	13.33	1.95	14.88	1.36	14.21	1.77	11.40	0.70
	Total	13.30	2.02	14.02	2.04	13.24	2.45	11.00	0.92

Table 8b

Awareness of Spatial Trajectory: Newman-Keuls Comparisons
(Grade Effect)

	Kdgtn.	1st.	3rd.
Kdgtn.		**	**
1st.			**

* $p < .05$
** $p < .01$

Table 9a
Recognition of Perspective (Task #9): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kdgtn.	Females	9.82	3.16	8.73	2.33	10.46	2.62	10.60	3.65
	Males	8.63	1.60	9.25	4.77	11.25	4.71	11.80	3.96
	Total	9.32	2.23	8.95	3.46	10.79	3.55	11.20	3.64
1st.	Females	11.36	3.70	12.54	3.11	15.36	2.38	12.60	3.98
	Males	12.18	3.37	14.45	3.86	16.45	1.29	15.40	3.78
	Total	11.77	3.48	13.50	3.56	15.91	1.95	14.00	3.94
3rd.	Females	12.63	3.01	14.82	2.68	15.82	1.99	15.00	2.12
	Males	15.67	1.78	14.17	1.27	17.83	0.58	17.60	0.90
	Total	14.22	2.84	16.04	2.34	16.70	1.74	16.30	2.06

Table 9b
Recognition of Perspective: Newman-Keuls Comparisons (Grade and Session Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.		**	**
1st			**

	Session 1	Session 2	Session 3
Session 1		**	**
Session 2			**

* $p < .05$

** $p < .01$

Table 10a

Representation of Perspectives (Task #10): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kdgtn.	Females	2.43	1.02	3.02	0.90	3.02	0.93	2.85	1.14
	Males	2.88	1.10	3.22	0.94	3.28	0.92	2.95	1.00
	Total	2.62	1.07	3.11	0.92	3.13	0.93	2.90	1.06
1st.	Females	3.07	1.19	3.07	0.97	3.39	0.84	3.05	1.00
	Males	2.84	1.26	3.09	0.96	3.25	0.81	3.15	0.88
	Total	2.95	1.22	3.08	0.96	3.32	0.82	3.10	0.93
3rd.	Females	3.11	0.99	3.34	0.86	3.36	0.86	3.45	0.83
	Males	3.21	0.99	3.29	0.85	3.46	0.80	3.25	0.79
	Total	3.16	0.99	3.32	0.85	3.41	0.83	3.35	0.80

Table 10b

Representation of Perspectives: Newman-Keuls Comparisons (Grade, Session, and Scene Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.			**
1st			

	Session 1	Session 2	Session 3
Session 1		**	**
Session 2			

	Scene I Trainman	Scene II Farmer	Scene I Woman	Scene II Woman
Scene I Trainman		**	**	**
Scene II Farmer			**	**
Scene I Woman				

* $p < .05$

** $p < .01$

Table 11a

Construction of Straight Lines (Task #11): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kdgtn.	Females	0.00	0.00	0.18	0.40	0.36	0.67	0.40	0.55
	Males	0.00	0.00	0.12	0.35	0.62	0.92	1.20	1.64
	Total	0.00	0.00	0.16	0.37	0.47	0.77	0.80	1.23
1st.	Females	0.36	0.67	0.55	0.93	0.73	0.47	0.60	0.89
	Males	0.45	0.82	0.45	0.52	0.91	1.04	1.60	1.34
	Total	0.41	0.73	0.50	0.74	0.82	0.80	1.10	1.20
3rd.	Females	1.18	1.21	1.36	1.12	2.55	0.69	1.40	1.14
	Males	2.00	1.40	2.50	0.52	3.00	0.00	2.80	0.45
	Total	1.61	1.34	1.96	1.02	2.78	0.52	2.10	1.10

Table 11b

Construction of Straight Lines: Newman-Keuls Comparisons (Grade, Session & Line Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.		*	**
1st.			**

	Session 1	Session 2	Session 3
Session 1			**
Session 2			**

	Line 3	Line 2	Line 1
Line 2			**
Line 3			**

* p .05
** p .01

Table 12a

Coordination of Perspectives (Task #12): Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kdgtn.	Females	1.42	0.71	1.58	0.50	1.94	0.39	1.87	0.52
	Males	1.71	0.55	1.67	0.48	1.88	0.34	1.93	0.59
	Total	1.54	0.66	1.61	0.49	1.91	0.39	1.90	0.55
1st.	Females	1.70	0.53	1.82	0.39	2.00	0.35	1.80	0.56
	Males	1.55	0.71	1.94	0.35	2.03	0.30	2.00	0.66
	Total	1.62	0.63	1.88	0.37	2.02	0.33	1.90	0.61
3rd.	Females	2.00	0.25	2.03	0.30	2.21	0.42	1.93	0.46
	Males	2.06	0.23	2.25	0.44	2.36	0.49	2.13	0.35
	Total	2.03	0.24	2.14	0.39	2.29	0.46	2.03	0.41

Table 12b

Coordination of Perspectives: Newman-Keuls Comparisons (Grade & Session Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.			**
1st.			**

	Session 1	Session 2	Session 3
Session 1		**	**
Session 2			**

* $p \leq .05$
** $p \leq .01$

Table 13a

Linear Order: Reversal, Transformation, and Anticipation (Task #13) : Means and Standard Deviations

		Session 1		Session 2		Session 3		Control	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Females	1.82	1.33	2.91	0.94	3.18	0.75	2.80	0.84
Kdgtn.	Males	2.12	0.83	2.25	0.89	2.75	0.71	3.00	0.71
	Total	1.95	1.13	2.63	0.96	3.00	0.75	2.90	0.74
	Females	2.64	1.03	3.09	0.94	3.45	0.82	2.40	1.52
1st.	Males	2.73	0.90	3.36	0.67	3.27	1.01	2.80	0.84
	Total	2.68	0.95	3.23	0.81	3.36	0.90	2.60	1.17
	Females	3.09	0.94	3.09	0.70	3.45	0.52	3.40	0.55
3rd.	Males	3.50	0.52	3.42	0.67	3.58	0.51	3.00	0.71
	Total	3.30	0.76	3.26	0.69	3.52	0.51	3.20	0.63

Table 13b

Linear Order: Reversal, Transformation, and Anticipation: Newman-Keuls Comparisons (Grade, Session & Task Effects)

	Kdgtn.	1st.	3rd.
Kdgtn.		**	**
1st.			

	Session 1	Session 2	Session 3
Session 1		**	**
			*
Session 2			

	Anticipation Reversal	Reversal Direct Order	Anticipation Direct	Transformation
Anticip. Reversal		**	**	**
Reversal Direct				
Anticip. Direct				

* p .05
** p .01

TABLE 14

Percentages of Subjects Passing Each Subtask for Tasks Included in Scalogram Analysis

	Session I	Session II	Session III
8: Single Airplane	89	97	100
8: Double Airplanes	97	98	100
8: Double Airplanes	97	98	98
3: Block Design A	95	98	98
3: Block Design B	86	97	97
13: Circular to linear order	77	92	97
2: Design #2, Top. Accurate	100	100	97
2: Design #7, Top. Accurate	91	98	97
2: Design #5, Top. Accurate	94	92	97
2: Design #3, Top. Accurate	93	98	95
2: Design #1, Top. Accurate	92	98	95
9: Recog. Perspect., Front Cheese	91	84	95
3: Block Design C	89	75	94
9: Recog. Perspect., Front Pig	95	98	94
6: Awareness Vertical, Recognition	86	98	92
13: Reversal of linear order	72	83	91
9: Recog. Perspect., Side Pig	73	84	91
8: Double Airplanes	72	58	91
13: Anticipation of direct order	83	89	89
9: Recog. Perspect., Front Cat	72	83	84
9: Recog. Perspect., Side Penguin	80	86	84
8: Single Airplane	52	67	84
8: Single Airplane	44	59	84
8: Double Airplanes	38	52	81
9: Recog. Perspect., Side Cat	41	70	81
9: Recog. Perspect., Side Cheese	64	78	81

TABLE 14 (cont.)

	I	II	III
8: Single Airplane	53	50	83
8: Double Airplane	48	48	80
9: Recog. Perspect., Back Penguin	56	78	76
9: Recog. Perspect., Back Cat	72	77	75
5: Measurement length, Line 2	61	70	75
6: Awareness of Vertical, Planting	88	52	73
5: Measurement of length, Line 1	55	64	70
9: Recog. Perspect., Back Cheese	52	59	70
8: Single Airplane	55	48	70
8: Double Airplane	30	25	69
3: Block Design 1	41	58	66
7: Awareness of horizontal, 90 degree	42	59	66
6: Awareness of vertical, Drawing	41	52	62
11: Construction straight line #1	30	44	62
2: Design #2, Eucl. Accurate	24	33	62
8: Single Airplane	47	48	61
13: Anticipation of reversed order	38	42	56
4: Conservation of length	20	39	50
2: Design #5, Eucl. Accurate	11	33	50
3: Block Design 3	22	38	45
3: Block Design 4	22	36	44
2: Design #8, Top. Accurate	25	16	44
2: Design #4, Top. Accurate	36	47	44
5: Measurement length, ruler relationship understood	16	30	42
11: Construction straight line #2	27	22	42
11: Construction straight line #3	16	27	37
2: Design #3, Eucl. Accurate	19	23	36

TABLE 14 (cont.)

	I	II	III
2: Design #7, Eucl. Accurate	19	34	33
5: Measurement length, ruler accurately used	22	33	33
3: Block Design 2	23	30	31
3: Block Design 5	11	17	31
7: Awareness of horizontal, 315 degree	16	31	31
2: Design #1, Eucl. Accurate	13	27	30
7: Awareness of horizontal, 45 degree	20	36	30
7: Awareness of horizontal, 135 degree	13	23	25
12: Coord. Perspect., 90 degrees	3	9	22
3: Block Design 6	5	8	20
2: Design #6, Top. Accurate	13	13	20
2: Design #6, Eucl. Accurate	11	27	19
2: Design #4, Eucl. Accurate	3	17	19
12: Coord. Perspect., 180 degrees	2	6	17
2: Design #8, Eucl. Accurate	3	16	12
3: Block Design #7	3	0	11

Table 15

Correlation Coefficients for Measurement and Conservation of Length

	Session 1	Session 2	Session 3
Kdgtn.	.33	.39	.60**
1st. Grade	-.11	.22	-.12
3rd. Grade	.59**	.11	.37

** $p < .01$